Power Engineering

JANUARY 1961

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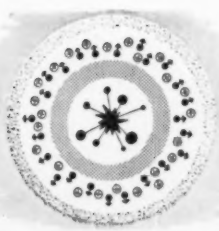
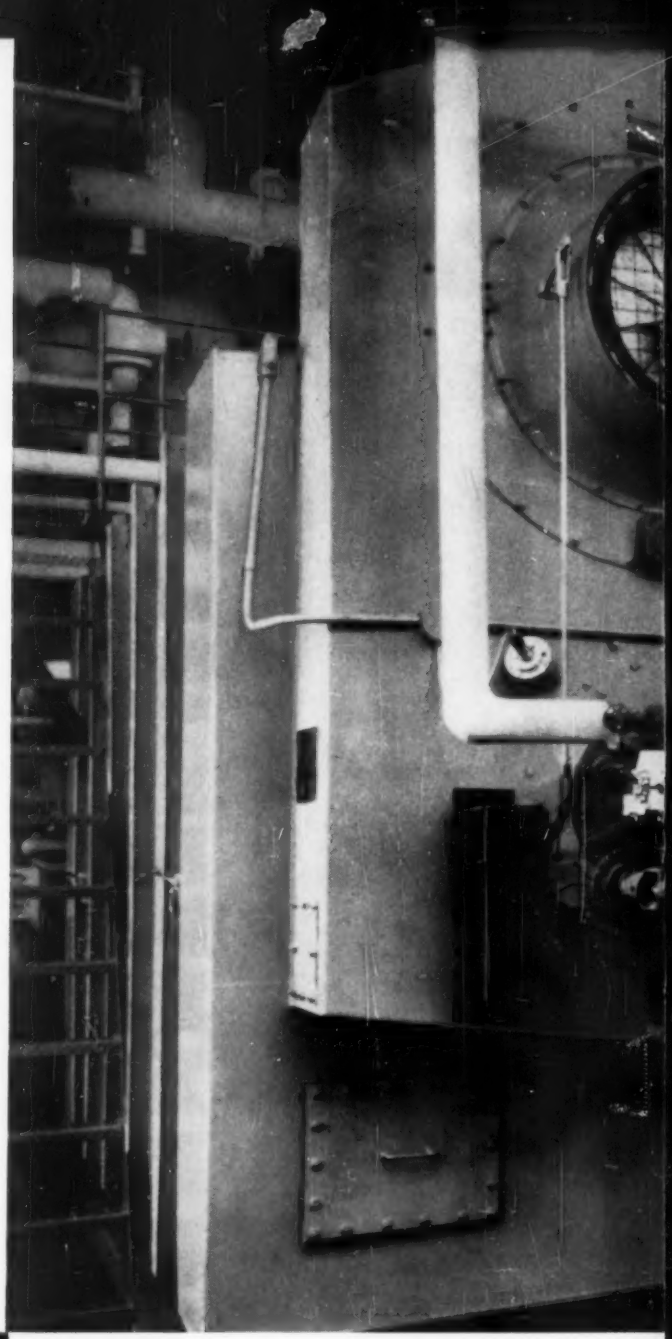


REPORT ON UNCONVENTIONAL POWER SOURCES

Rx

For Steam at Holy Cross Hospital

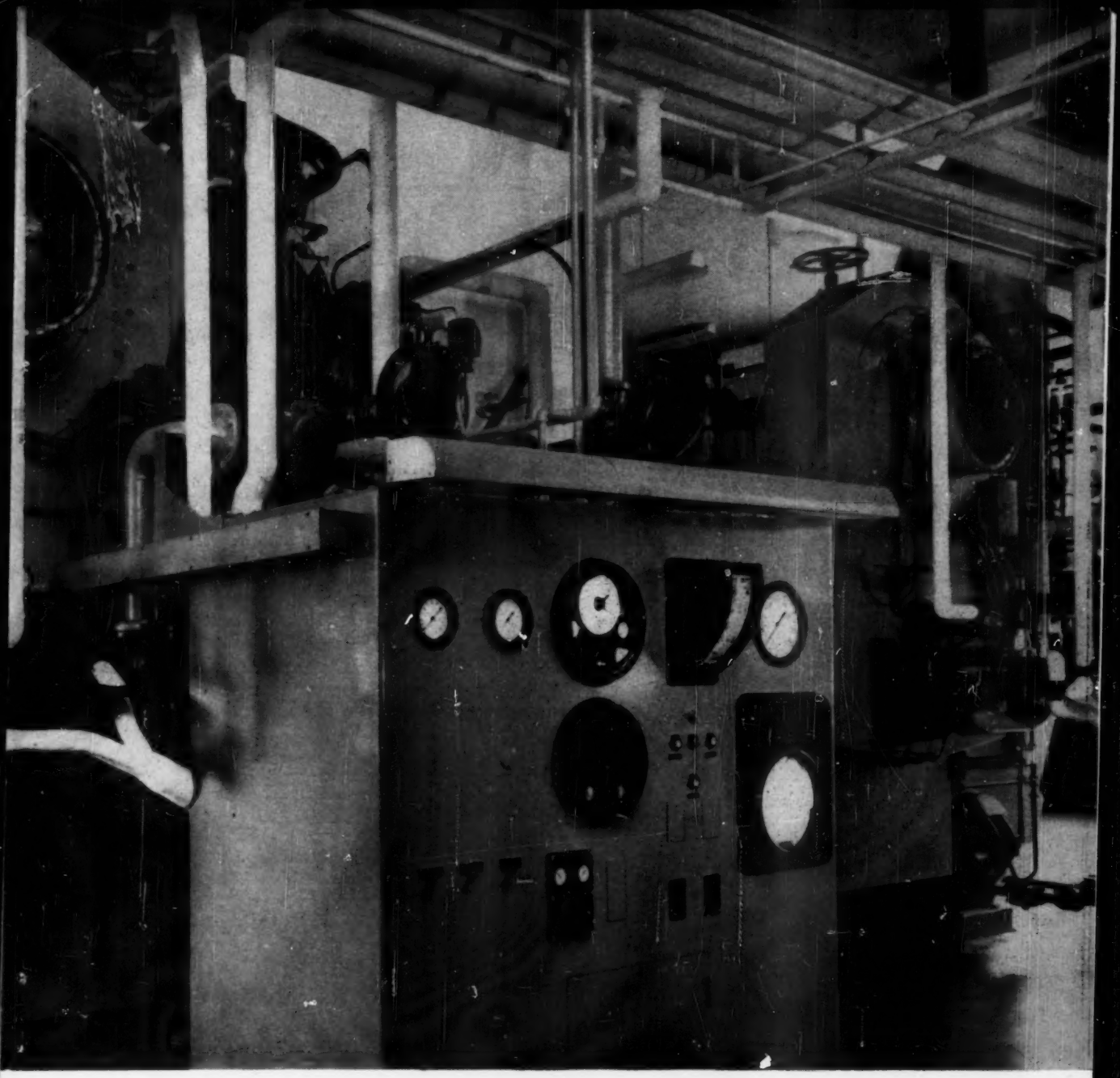


Two new oil and gas-fired B&W Package Units dependably meet crucial 40,000-lb-per-hour steam requirement at well known Chicago hospital

Day after day, year after year, each and every hospital activity is vital. This continuous, reliable hospital service must, of course, be supported by absolute dependability in equipment.

That's why so many institutions such as Chicago's Holy Cross Hospital have selected B&W Package Boilers to meet their steam requirements. Supplying clean, dry steam for critical uses such as heating, laundry, kitchens and sterilizers, B&W Package Boilers have become a standard of dependability in hospitals and other institutions throughout the nation.

Dependability, however, is only part of the story. Budget-



minded hospital management has found the low maintenance, cleanliness of operation, high operating economies, flexibility, rapid response to demand and maximum capacity in minimum space afforded by B&W shop-assembled units equally attractive features. What's more, they appreciate the assurance that at any time during the life of the boiler, even 20 or 30 years hence, B&W's nationwide service organization will be promptly and economically available if needed.

Serving the myriad steam requirements of a vital installation like Chicago's Holy Cross Hospital is further evidence in action of dependable steam generation by B&W. Whatever *your* steam requirements . . . whatever your most economical fuel . . . B&W has the boiler best suited to your application. Your local B&W representative has all the facts on your area. Please call him soon. The Babcock & Wilcox Company, Boiler Division, Barberton, Ohio.

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TO 1000 FEET

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Improved Polyethylene
GREATER CHEMICAL RESISTANCE

Dekoron New Metl-Cor is an exciting instrument harness design that simplifies and speeds installation of tubing... makes neater and tidier tubing installations — because New Metl-Cor, with exclusive parallel-tube construction, is now number-coded every 2 inches.

That means there's no delay caused by trial-and-error compressed-air testing of lines. Follow the number code and hook-up correctly the first time. There's no untwisting of corkscrew tubes. Peel the sheath back and connect straight lines fast. Dekoron New Metl-Cor also features an improved polyethylene sheath for maximum corrosion and impact protection and proven Dekoron quality — all at no increase in price.

Tube up with the best... it costs you less. Tube up with Dekoron products — instrument-engineered by instrument engineers. A-3711A

Dekoron Metl-Cor installs in record time because it needs no straightening, bends readily... has no "low spots, moisture traps."

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INSTALLS FASTER

Parallel Tubes
NEATER TAKEOFFS

Core Tubes
COPPER OR ALUMINUM

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Power Engineering

POWER ENGINEERING is published monthly at 308 E. James Street, Barrington, Illinois. Telephones: Dunkirk 1-1840, (Chicago) NEwcastle 1-0488.

Change of Address: Send to POWER ENGINEERING, Circulation Division, Barrington, Illinois. Please supply your position title, company name, company address. Please allow 60 days to make the change effective.

Subscription Information: Published monthly, price in the U.S. and possessions $10 per year; in Canada $11 per year; other countries $12 per year; single copies $1.

Indexed in the Industrial Arts Index and the Engineering Index on file in public and many private libraries.

Microfilm Edition: Request prices from University Microfilms, Inc., Ann Arbor, Mich. All volumes since 1948.

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For sixty years we've followed the developments in the power field—and only that! Why? Because it is the most dynamic business in the world! We've seen the old steam engine replaced by the modern supercritical boilers and turbine-generators, and the original carbon-filament light bulb replaced by the present-day fluorescent—and electro-luminescent—lighting.

Now, we launch into a new era, one filled with more power "miracles" than we've ever dreamed of before! New devices and equipment—all requiring electrical power—are reaching the market every month. And this means that we become more power-hungry each year!

This issue of POWER ENGINEERING *discusses the very newest energy sources—those known as* exotic power. *These are still in the developmental stage, but will certainly hold a prominent position in the future of the power field.*

Bob McCaw
EDITOR

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Engineers' Preview

OF NEWS AND COMING EVENTS IN THE POWER FIELD

DOVER, capital of Delaware, is to get a $9 million thermal power plant, with commercial operation scheduled for early 1962.

To be known as the McKee Run Electric Generating Station, the new plant will have an initial total installed capacity of 33,000 kw with an ultimate future capability of 143,000 kw. Contract for the design, engineering, procurement and construction management of the new plant has been awarded to the Kuljian Corp.

Initially, the plant will house two 16,500-kw turbine generators; two 160,000 lb/hr semi-outdoor boilers, 850 psig, 900 F, with pulverized coal firing and with gas as an alternate fuel and oil as a standby.

AVERAGE total professional income of engineering teachers has increased by 14.7 per cent in the past two years, according to a report by Engineers Joint Council. Over 5000 engineering teachers were surveyed. Today's average basic teaching salary for engineering teachers in American colleges is $8534. It is supplemented by an average of $2479 from outside professional income.

PENNSYLVANIA ELECTRIC CO and Warren Electric Cooperative have proposed to the Federal Power Commission that they jointly study the power potential of the proposed Kinzua Dam to be built by the U. S. Army Corps of Engineers on the Allegheny River near Warren, Penna.

The Warren Coop has in mind construction of a hydro plant of about 17,500 kw; a possible re-regulating dam 2½ miles downstream that could increase output to 30,000 to 75,000 kw; and a pumpback arrangement that would yield 50,000 to 125,000 kw.

Penelec's idea is to build a plant which would use coal-produced electricity during off-peak periods to pump water from the Allegheny River Reservoir to a hilltop reservoir nearby. During on-peak periods this water would be released to operate hydro generators.

AN EIGHT-MILLION electron volt linear accelerator is being built for A. O. Smith Corp's Milwaukee plant by the High Voltage Engineering Corp. This X-ray machine is designed to see through steel more than a foot thick and to furnish photographic proof of the soundness of such metal structures as core barrels for nuclear reactors and high pressure vessels for the petrochemical industry.

LARGEST nuclear research reactor in the Far East, at Tokai-mura, some 70 miles from Tokyo, Japan, has been turned over to the Japan Atomic Energy Research Institute by American Machine & Foundry Co, who made it for the Institute. The $1,500,000 reactor will open up a new era in Japan's extensive scientific research programs and in the teaching of nuclear techniques. Mitsubishi Atomic Power Industries played an important role in the fabrication of equipment and installation of the reactor, as a subcontractor to AMF.

DETROIT EDISON's total utility revenues of $277,458,000 for the twelve months ended October 31 were up 4.7 per cent. Improvements were shown in all the following electric revenue classifications:

Domestic sales were $107,130,000 — up 4.8 per cent; commercial sales, totaling $74,304,000, were up 4.5 per cent; industrial sales, at $75,506,000, rose 5.2 per cent; municipal and miscellaneous sales showed an 8.2 per cent improvement to $13,310,000.

Remainder of the total utility revenues were in non-electric classifications — steam sales of $7,157,000, and water sales of $51,000.

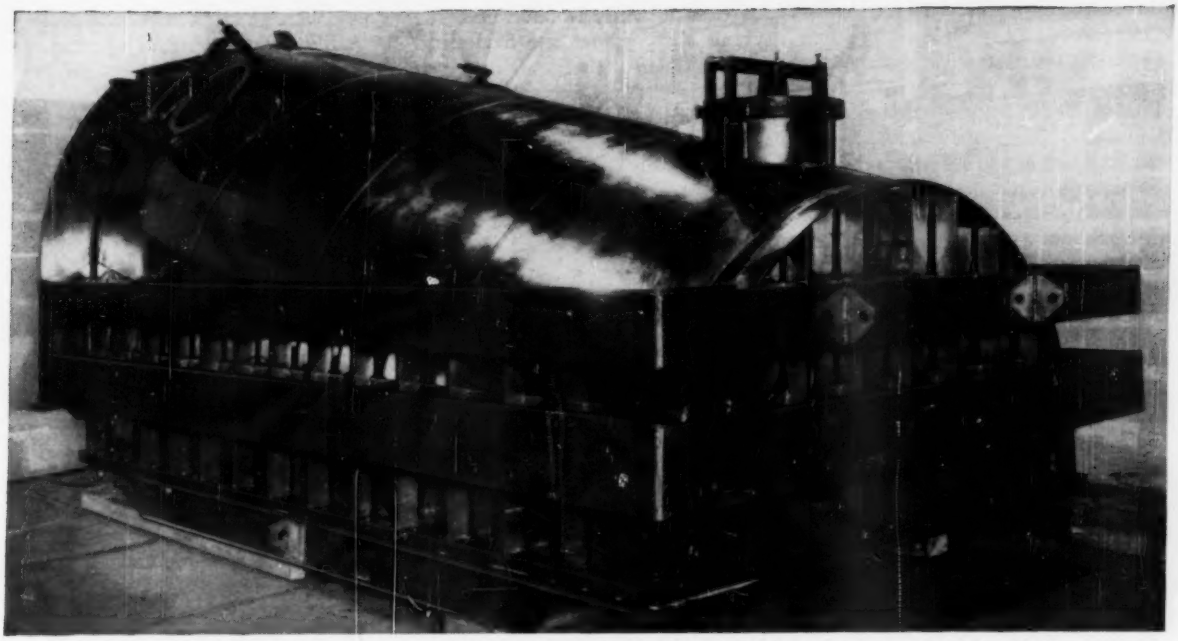
Net earnings increased for the 12-month period by 8.7 per cent — reaching $2.62 per share as compared to $2.41 for the corresponding period of 1958–9.

VALMONT STATION of the Public Service Co of Colorado, near Boulder, will get a $26 million, 150,000-kw generating unit. Engineering and design of the unit will be done this year, major construction in 1962–63. This addition will bring Valmont Station's generating capability to 274,000 kw. The job is part of a $54 million program in new construction recently authorized by the company.

NEWS from the extra-high voltage front:

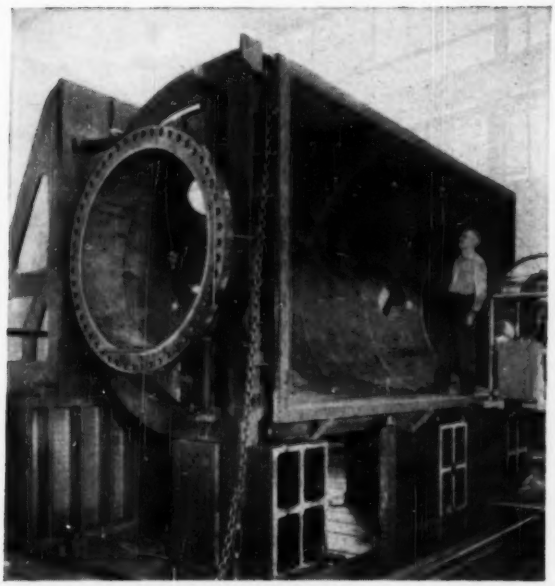
GE's Project EHV, at Pittsfield, Mass., was energized Dec. 8, and will operate for the next few years at a range of 460 to 750 kv. It is a complete testing ground with 158 measurements for electrical, mechanical and meteorological data. Over 225 instruments will be used. Dr. Pier Abetti, director of the project, will describe details of the work in an early issue of POWER ENGINEERING.

Cornell University's EHV cable testing station has recently been opened. This $3 million project is a joint effort on the part of the



COMPLETED AMBRALOY WATER BOX, one of eight, for 198,000-sq.-ft. twin-shell condenser in Consolidated Edison Company's Astoria No. 4 Unit. Boxes fit on tube sheets of Everdur—each 8' x 14' x 1½"—produced by Anaconda American Brass Company. Box is stiffened by steel ribs welded to the shell and to two heavy steel reinforcing bars.

New long-life water boxes fabricated from Ambraloy improve water flow—are ⅓ weight of cast boxes



WATER BOX ON A VERTICAL BORING MILL during construction at C. H. Wheeler Mfg. Co. plant, Philadelphia. The shell is fabricated from hot rolled Ambraloy-930 plate, ⅜" gage throughout. At main seams, segments are prebeveled by grinding and joined by butt welding. Fillet welds are used to attach inlet nozzles, manholes, vents, and stiffener ribs. Most of the welding was done by the inert-gas consumable-electrode process; inaccessible joints were made by manual metal-arc welding with flux-coated electrodes.

Streamlined water boxes built by C. H. Wheeler Mfg. Co. for Consolidated Edison Astoria Unit No. 4

Fabricated from a strong wrought copper alloy, they offer some interesting advantages over cast iron boxes.

1. Weight savings—under 17,000 pounds compared with 45,000 pounds for cast boxes—easier to ship and handle in installation and maintenance.

2. Wider latitude in water box design. Conical shape of boxes streamlines flow of cooling water, minimizing turbulence and eddy currents which affect tube life.

3. Long service life. Unlike cast iron boxes, which rust and leave corrosion products detrimental to tubes and tube sheets, nonferrous boxes are highly corrosion resistant.

Engineers at C. H. Wheeler Mfg. Co. consulted Anaconda metallurgists for suitable alloys combining high strength, weldability, and high corrosion resistance. The relative merits of Cupro Nickel, 10%-755, used for water boxes in Naval condensers, Ambraloy-930 (aluminum bronze) and Everdur®-1010 (copper-silicon alloy) were considered, and as a result Ambraloy-930 was selected for this particular installation handling polluted sea water from New York's East River.

Anaconda American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ontario.

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Association of Edison Illuminating Companies and the Edison Electric Institute; four cable manufacturers — Anaconda Wire and Cable, Phelps Dodge Copper Products, General Cable, and The Okonite Co; two terminal manufacturers — G & W Electric Specialty Co and Ohio Brass; and one pressurizing equipment manufacturer — Jerome Hydraulics Co. New York State Electric & Gas is the service utility involved.

During the first two years of testing, the voltage will be raised gradually from 345 kv; then will follow testing at elevated temperatures and voltages up to 500 kv.

Construction is well advanced on a 7-mile section of 460,000-v transmission line which TVA is building in middle Tennessee to gain experience in designing and building lines of extra-high voltage. This project is part of a transmission line for operation at 161,000 v which is being built from TVA's Johnsonville Steam Plant to Lawrenceburg, Tennessee. While the experimental section is insulated for 460,000 v, it too will be operated initially, at least, at 161,000 v. Estimated cost of the experimental section is about $100,000 a mile.

A new high-voltage experimental transmission line has been built by Westinghouse to study problems concerned with radio-influence and corona loss. The single-phase woodpole line is located at Trafford, Pa., near the company's high-voltage laboratory. The line is energized from the laboratory and is operated at voltages up to 200 kv to ground.

GENERAL ELECTRIC has announced a gas turbine package power plant which can be purchased for $100/kw and can be in operation ten days after delivery. South Carolina Electric and Gas Co is reported to have purchased four of the new package units.

Powered by an 11,000-kw gas turbine, the package plant is a compact, self-contained generating station capable of operation in conjunction with other generating equipment or as an isolated and independent station. It can start without any external source of power and reportedly can be on the line at full load in less than 15 minutes.

Cooling system does not use external water, and the ability to start and operate while isolated from the system also permits site flexibility. The dual fuel system (gas or distillate oil) can be arranged for change under load or while shutdown and permits the use of the most economical fuel.

The station is basically designed for remote unattended operation but can also be run as a locally operated, manually controlled installation.

A MILLION MAN-HOURS without a disabling injury — that's the record chalked up recently by the 260 employees of AEP's Philip Sporn Plant. This remarkable safework span began in 1958. During 1959, the plant's employees received three awards for safety efforts. One came from Edison Electric Institute, two others from within the AEP organization.

RIVERSIDE POWER STATION of Gulf States Utilities Co, at Lake Charles, La., will be modernized for operation with computer equipment. When completed, the plant will have the necessary controls to allow two Allis-Chalmers turbines — a 35,000 and a 40,000-kw unit — to be started automatically when required for peak loads and shutdowns as the load decreases. The computer will continuously calculate the heat rates of the station so that the plant can be automatically regulated at all times.

As prime contractor, Allis-Chalmers will design, furnish and install the system for automatic control. Instrumentation and data processing system will be made by Consolidated Systems Corp, Bell & Howell and Consolidated Electrodynamics.

580-MW nuclear power plant, biggest yet, will be built at Sizewell on Britain's east coast, in Suffolk. The $155-million contract covering the project has been awarded to the English Electric, Babcock & Wilcox, Taylor Woodrow Atomic Power Group. With two turbine generators only — each of 325 Mw — Sizewell will be the most compact of Britain's seven commercial atomic stations. Sizewell will have two gas-cooled graphite-moderated reactors.

With this station, total power of Britain's nuclear power plants reaches 3000 Mw, or over 10 per cent of the country's present generating capacity.

MARK YOUR CALENDAR:

AIEE's winter general meeting is scheduled for Jan 29–Feb 3, in New York City.

National Society of Professional Engineers will hold its winter meeting Feb. 9–11 at Hotel Fort Des Moines, Des Moines, Iowa.

Association of Diesel Specialists meets Feb 23–26 at the Granada Hotel and Inn, San Antonio, Texas.

12th Western Metal Congress and Exposition will be presented by the American Society for Metals March 20–24 in Los Angeles' Pan-Pacific Auditorium and Ambassador Hotel.

Annual convention of the Illinois Society of Professional Engineers will be held in Peoria, April 20, 21 and 22.

United Nations conference on new sources of energy is planned for August 21–31, at Rome. Executive secretary of the conference is Alfred G. Katzin of the U.N. in New York.

NEWS IN RESEARCH: Polytechnic Institute of Brooklyn has been awarded a grant of $375,000 by the National Science Foundation to support the construction of graduate level research laboratories. The laboratories will be established in Polytechnic's Long Island Graduate Center.

Chase Brass & Copper has established a condenser tube clinic. Under the direction of J. J. Vreeland, the clinic will work with various companies on analysis of water, tube failures, corrosion problems and metallurgy.

NEMA reports that the electrical industry will spend $4 billion for research and development work this year — more than all of the rest of the nation's industries combined.

OIL provides two-fifths of the energy used in this country today; coal and natural gas, about one-fourth each; hydropower and natural gas liquids, the remainder. So reports Fred A. Seaton, Secretary of the Interior. He also points out that while the coal industry's production in 1901 was about 293 million tons, today it is over 430 million tons.

Professional consensus is that the United States in 15 years will be using 85 per cent again as much energy as five years ago. For coal this could mean an increase of some 75 per cent over 1955.

Get 31% more filming action with Dearborn's Super Filmeen®

In either flake or emulsion form, Super Filmeen—a development of Dearborn's research laboratories—has been proved 31% more active than ordinary octadeclyamine acetate . . . is not subject to dehydration at super-heated steam temperatures . . . will not hydrolyze to acetic acid . . . remains alkaline in feed solutions.

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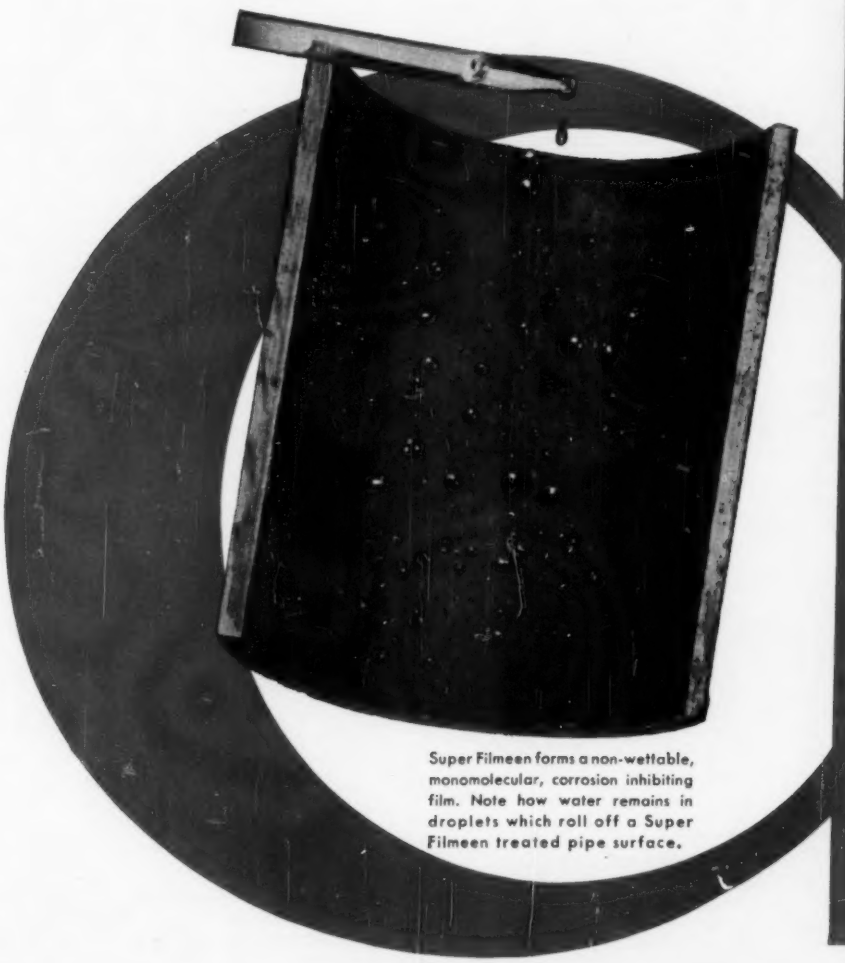

Super Filmeen forms a non-wettable, monomolecular, corrosion inhibiting film. Note how water remains in droplets which roll off a Super Filmeen treated pipe surface.

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Tracers

COMMENT, OPINION, AND NEWS ABOUT PEOPLE

▶ **Paul F. Dickens,** production superintendent of the Electric Utility System of Farmington, N. M., has been a faithful reader of POWER ENGINEERING for 37 years. He writes:

> May I have one copy each of your reprints, Successful Training for Power Plant Operators, and Motor Bearings, as mentioned in your October issue?
>
> I find application and use of articles from former reprints in the operation and maintenance of power plants to be successful in establishing greater plant economies. I thank you so much for all the good things that come from your magazine, which I started reading in May, 1923. I am sure they have been a contributing factor to my climb and success in the power plant game.

▶ America has no cause to worry about a water shortage — either now or in the year 2000. So says **Dr. Richard D. Hoak,** head of the American Iron and Steel Institute's Water Resources Research Project at Mellon Institute in Pittsburgh. Dr. Hoak points out that those who predict an impending national water shortage tend to confuse use with consumption, and do not realize that most of the water withdrawn by industries and municipalities is really reused.

> Recent figures on current uses of water in the United States suggest that the country needs 231 billion gpd for all purposes. Breaking down this total by uses, Dr. Hoak estimates there actually is 100 per cent consumption only in rural use, 10 per cent consumption in municipal and industrial withdrawals, 1 per cent for steam-power generation, and 60 per cent for irrigation. The total of these consumptions is only about 72 billion gpd, representing the supply of new water really needed to support all uses.
>
> Nationally, rainfall runoff to streams amounts to an average daily supply of about 1.22 trillion gpd, which Dr. Hoak says is potentially available for use. Water engineers believe it ultimately may be economically feasible to develop some 635 billion gpd from this rainfall runoff. That figure, says Dr. Hoak, can probably be raised to about 650 billion.
>
> But in answer to the question of why we should conserve water, in view of the large average excess over actual needs, Dr. Hoak offers strong reasons for conservation. While the country has an ample national water supply, as shown by average figures, many areas have too much or too little, depending on the season, and droughts unbalance regional water economics. Local water-supply problems also are aggravated by increasingly heavier concentration of industry in the more heavily populated areas.
>
> Dr. Hoak thinks there is good reason to believe that reuse of water by industry should be one of the most important technological developments of the next 10 to 25 years.

▶ Now is the time to appraise the prospects of the investor-owned power companies under a new administration in American government. **The Value Line Investment Survey** of New York comments:

> Announced plans for new generating capacity over the next four years suggest that the 75–25 ratio between private and public kwh output will hold in the foreseeable future. The change of administration should not result in mushroom growth of public power at the expense of the investor-owned utilities.
>
> Electric utilities should continue to prosper. Threat of further inroads by public power appears to have been over-rated. A large segment of the utility industry is not affected by Federal power at all. Furthermore, the scope of government expansion into the field is limited. Moreover, government projects are not exclusively to the detriment of the investor-owned companies.
>
> Finally, an examination of the composition of the new Congress finds no important shift in strength in the public power-private power camps.

▶ **James N. Landis,** vice-president of the Bechtel Corp, has been elected president of Engineers Joint Council. Landis succeeds **Augustus B. Kinzel,** vice-president of Union Carbide, who headed EJC for the past year. **George E. Holbrook,** vice-president of DuPont, was re-elected EJC vice-president.

New president of Daystrom, Inc, is **John B. Montgomery,** a former Air Force major general and formerly vice-president and general manager of General Electric's Flight Propulsion Division. **Thomas Roy Jones,** president of Daystrom since 1932, has become chairman.

A. D. R. Fraser, president of Rome Cable Div of Alcoa, will head the National Electrical Manufacturers Assn for the coming year.

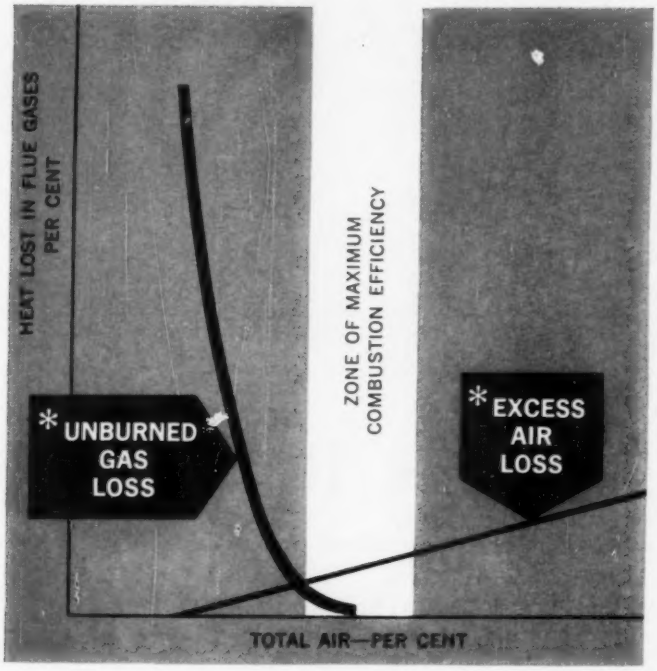
Three electrical manufacturers have been honored by NEMA "in recognition of their outstanding personal contributions to the progress of the electrical industry." These award winners are: **N. J. MacDonald,** president of the Thomas & Betts Co; **James Finney Lincoln,** chairman of the board of the Lincoln Electric Co; and **Everett Morss,** president of Simplex Wire and Cable Co.

United Engineering Trustees, Inc, an organization of five major national engineering societies, has elected **Willis F. Thompson,** of New Haven, Conn., as president. Thompson is executive vice-president of Westcott and Mapes, Inc.

Mervin J. Kelly of Bell Laboratories has been given the Golden Omega Award, which is presented annually by the National Conference on the Application of Electrical Insulation.

Carl E. Lesher, consulting engineer, of Pittsburgh, has been given the Percy Nicholls Award "for notable scientific or industrial achievement in the field of solid fuels." The award is given jointly by the American Institute of Mining, Metallurgical and Petroleum Engineers and by ASME.

You must know BOTH* to get maximum combustion efficiency!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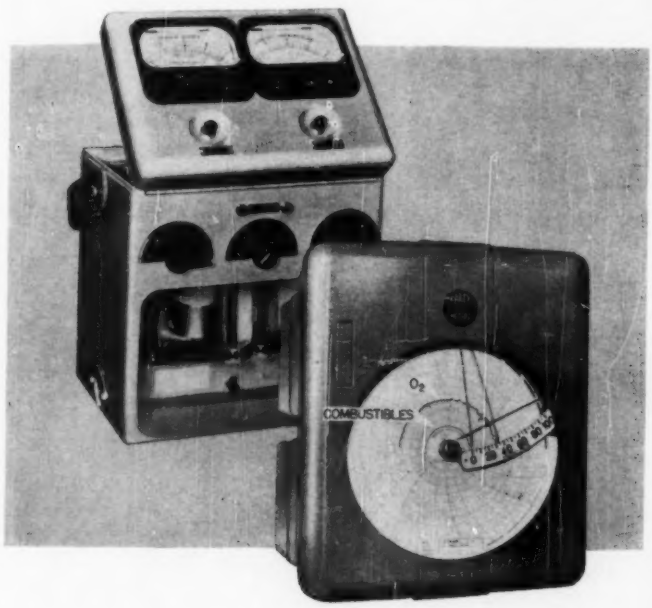
* EXCESS AIR LOSS
TOTAL AIR—PER CENT

How much money is going up the flue in *unburned fuel* losses? Is too much air resulting in excessive *heat* losses?

You must know *both* facts—simultaneously—to get optimum combustion. No instrument that measures only one of these interdependent factors can give you the full information you need.

Bailey offers a choice of two direct ways to maintain a continuous and simultaneous double check on these factors that determine combustion efficiency. The portable, lightweight Bailey HEAT PROVER Analyzer indicates both; the Bailey Oxygen-Combustibles Analyzer-Recorder records both on a single chart. Both instruments measure excess air, regardless of fuel or fuels being burned, and per cent of combustibles in flue gas.

Either of these Bailey instruments can save you far more than their cost in spotlighting combustion inefficiencies. Ask your Bailey engineer or write for product specifications.



2 DIRECT WAYS to measure both combustibles and oxygen simultaneously

PORTABLE INDICATOR—Self-contained, lightweight, Bailey HEAT PROVER Analyzer enables quick, easy check on combustion conditions. Dual range dials for greater accuracy and readability.

PERMANENT RECORDER—Bailey Oxygen-Combustibles Analyzer-Recorder coordinates both records on one chart . . . is designed for permanent installation . . . helps maintain optimum ratio continuously.

* Unburned gas loss and excess air loss.

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HELPFUL WATER CONDITIONING DATA FROM BETZ

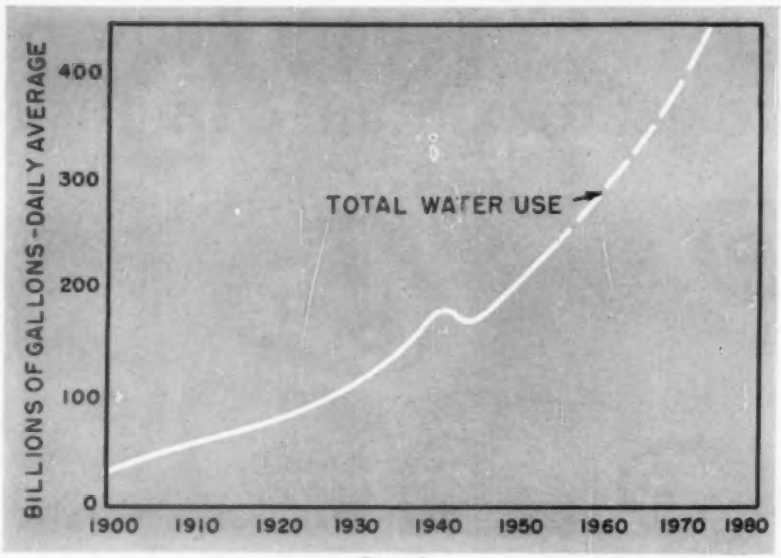

Figure 1

WASTING WATER IN YOUR

There are ample opportunities for the conservation of water in most industrial plants

WATER IS ONE of our most vital resources. Considerable concern has been expressed from time to time over the adequacy of our water resources. This concern is justified because of the enormous current water usage and the rate of increased usage predicted for the future as shown by Figure 1. The current water usage by industry alone is estimated as 70 billion gallons per day. It is anticipated that daily usage will soar to 115 billion gallons by 1975. Water requirements for various industries are typified by the data presented in Figure 2. With an expanding population and industrial growth it is important that serious attention by industry be given to the conservation and reuse of our water resources.

Industrial plants that are located in drought areas have been forced to cope with a water shortage problem much sooner than anticipated. In some of these cases, sewage plant effluent has been used for makeup to boilers and recirculating cooling water systems. The problems encountered in the treatment of sewage plant effluent to make it suitable for these purposes is thoroughly covered by Betz Technical Paper No. 138, a copy of which is available on request.

Many industrial plants located in other areas where water supplies have been considered adequate and inexhaustible, have found it profitable to conduct surveys of their water usages. Often, surveys of this type uncover unnecessary water losses, inefficient operations and equipment obsolescences. The correction of these conditions has led to a saving not only in water, but of dollars as well. A recent survey conducted at a chemical processing plant dramatically illustrates what can be done.

TYPICAL WATER REQUIREMENTS

Industry	Gallons per Tons
PETROLEUM	35,000
STEEL	65,000
PAPER	70,000
RUBBER	30,000

Figure 2

Case History

A chemical processing plant, considering an expansion program, found that the water supplies might not prove adequate for the anticipated operating conditions. The normal source of well water was already being supplemented by the use of city water which was already in short supply. One of the three wells normally used had been abandoned because of evidence of salt water intrusion. A simplified flow sheet of water usage for the plant is illustrated by Figure 3.

The survey revealed that a large quantity of hot condensate was being dumped to waste because of frequent contamination from process evaporators which introduced foam producing materials into the condensate. When this condensate returned to the boilers, severe boiler water carryover occurred.

Trouble also occurred with the lime-soda softener. The supplemental use of city water along with the normal well water created such a wide variation in makeup water characteristics that it was impossible to maintain proper balances. These poor balances resulted in the need for frequent backwashing of the filters and the maintenance of an abnormally high blowdown rate on the boilers.

The recirculating cooling water system contained numerous bleed-off points for miscellaneous water usages which made it uneconomical

to treat the system for prevention of corrosion. The corrosion products that accumulated were interfering with heat transfer, requiring added water flow to maintain process temperatures.

Briefly, the corrective measures applied involved the application of an *antifoam to the process evaporators* which eliminated contamination of the condensate. As a safety measure, however, an alarm system was installed which also operates a valve to divert the condensate, if and when contamination occurs. The return of the hot condensate materially reduced makeup requirements to the boiler so that the available city water proved more than adequate to handle boiler makeup requirements for the proposed operating conditions. With the use of city water alone for makeup to the boilers, uniform softener balances have been maintained and the filter backwash and boiler blowdown have been reduced to normal requirements.

Savings in heat, water treatment and water requirements far exceed the cost of the process antifoam and the cost of the alarm system used to correct the problem.

In addition, a check of the numerous draw-off points from the cooling system revealed unnecessary waste of water through open-ended hoses used periodically for washing equipment and left running. Cooling water for bearings and compressors was not returned to the main cooling water system. Elimination of these water losses permitted the cooling system to cycle and decreased makeup requirements to the point where the two existing wells could satisfy the water demands. These savings in water, in turn permitted corrosion control treatment to be justified economically. A check of the third well which had been abandoned for evidence of salt water intrusion indicated that the salt content was within a range to permit its use in the cooling system if necessary. This well was connected for emergency use to the cooling system. The effectiveness of the cooling water corrosion control treatment has limited corrosion of the steel parts in the system to less than one mil per year. Design temperatures and normal pressure drops through the heat exchangers are now maintained.

PLANT ?

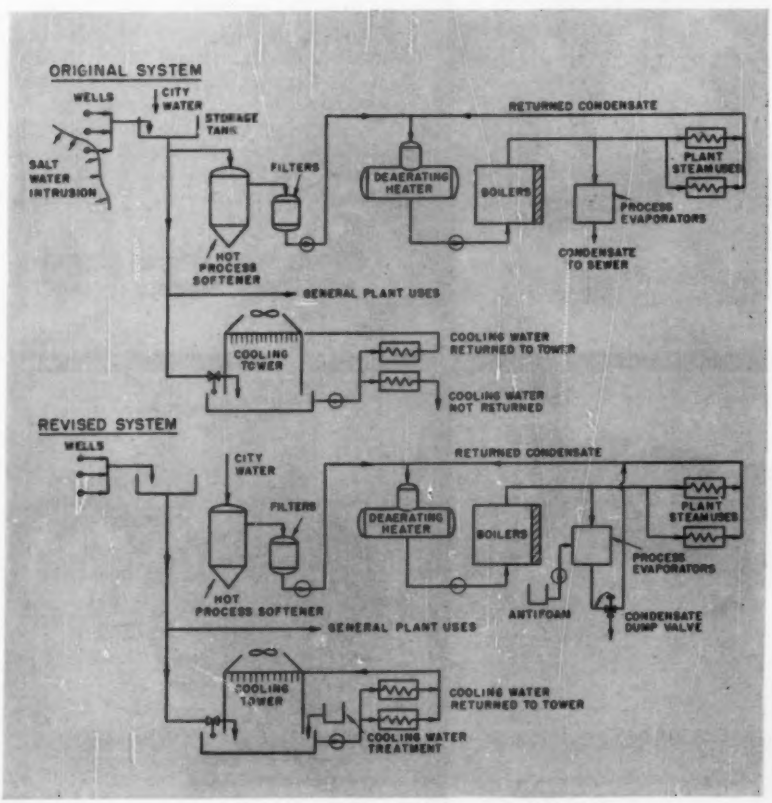

Figure 3

This survey and numerous others conducted by the Betz Consulting Division has revealed that there exist ample opportunities in many plants to bring about water conservation and oftentimes water re-use.

A survey of your plant water usages, treatment methods and water wastes may produce benefits both in water savings and dollar savings. Perhaps a process antifoam may be the answer. Talk it over with the Betz Engineer next time he visits your plant.

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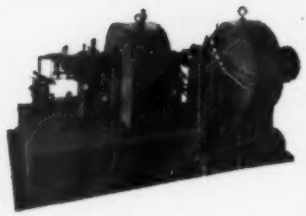

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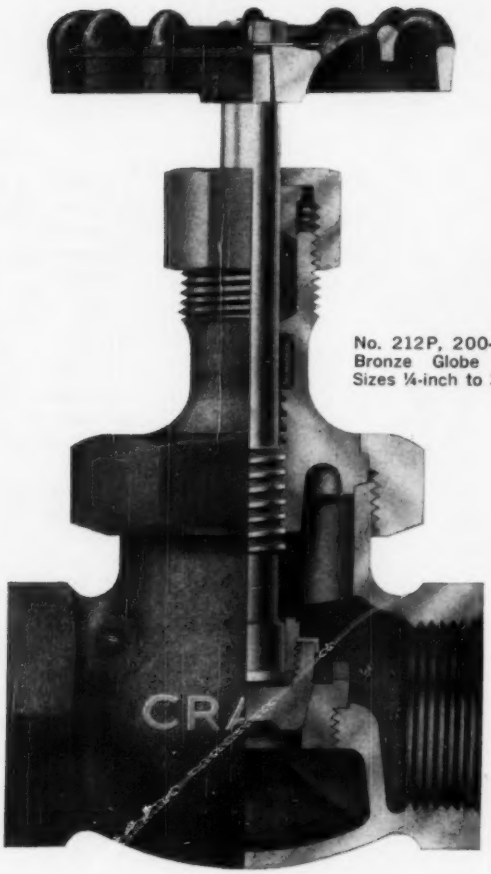

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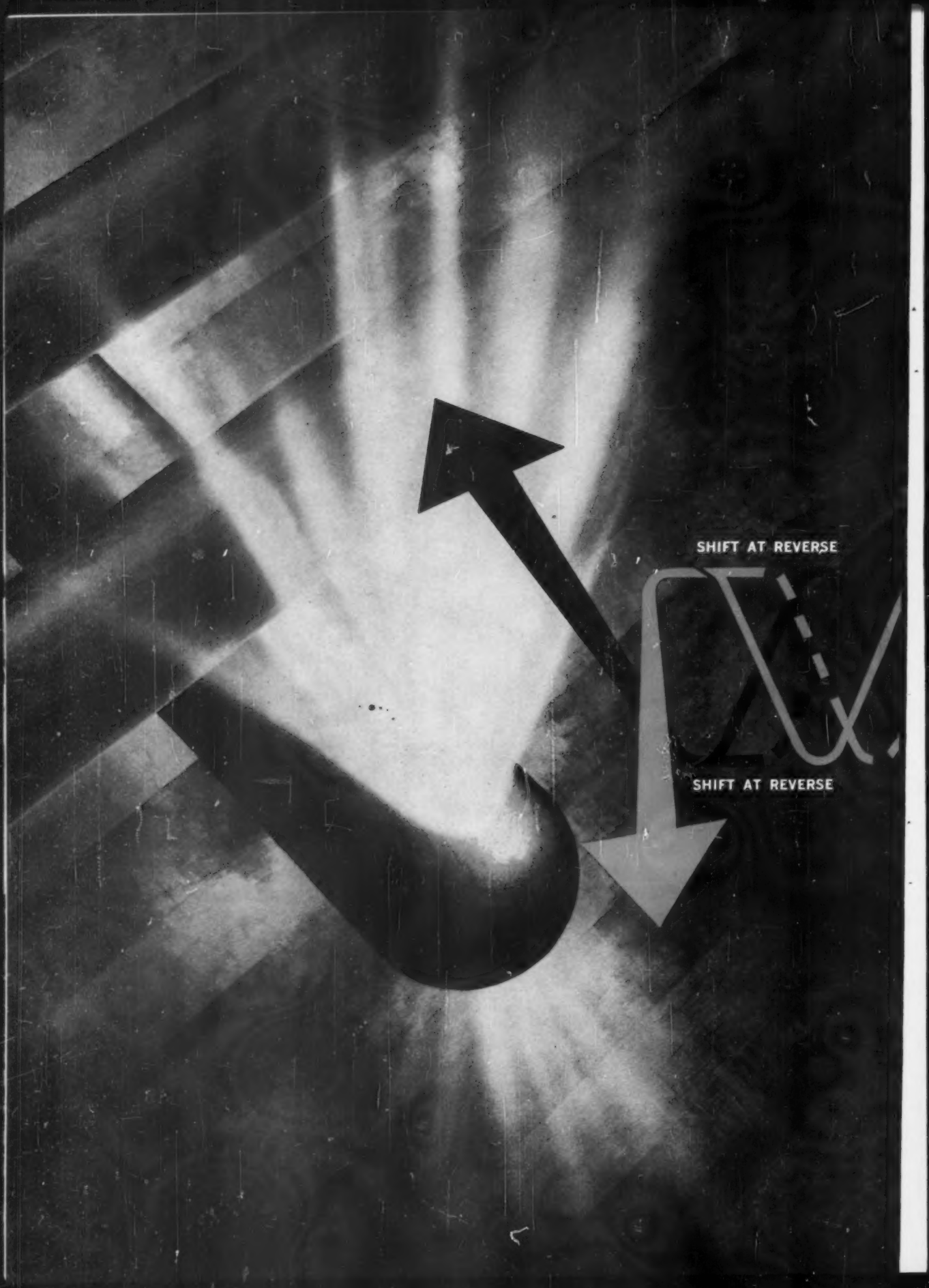
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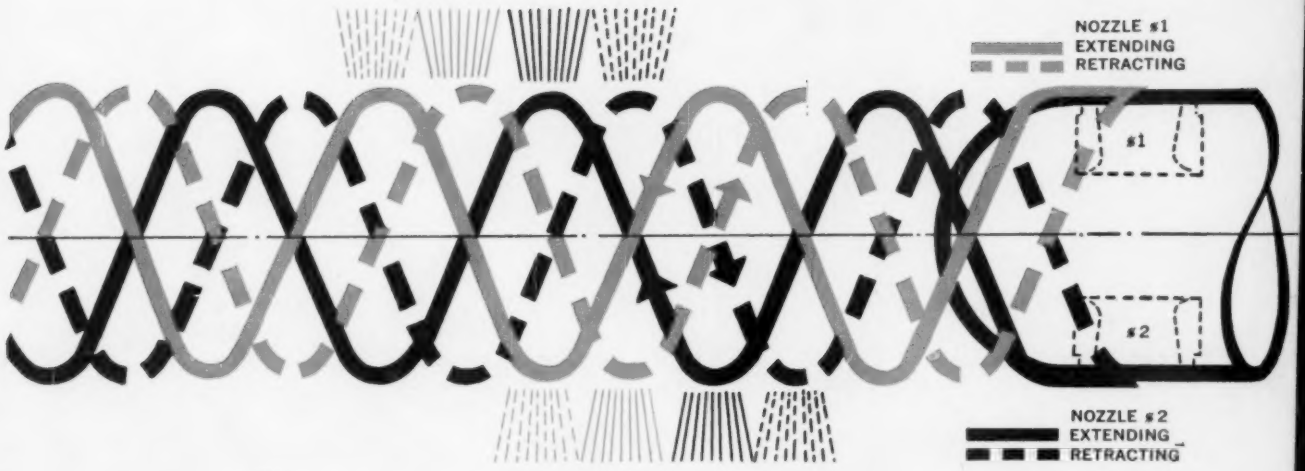

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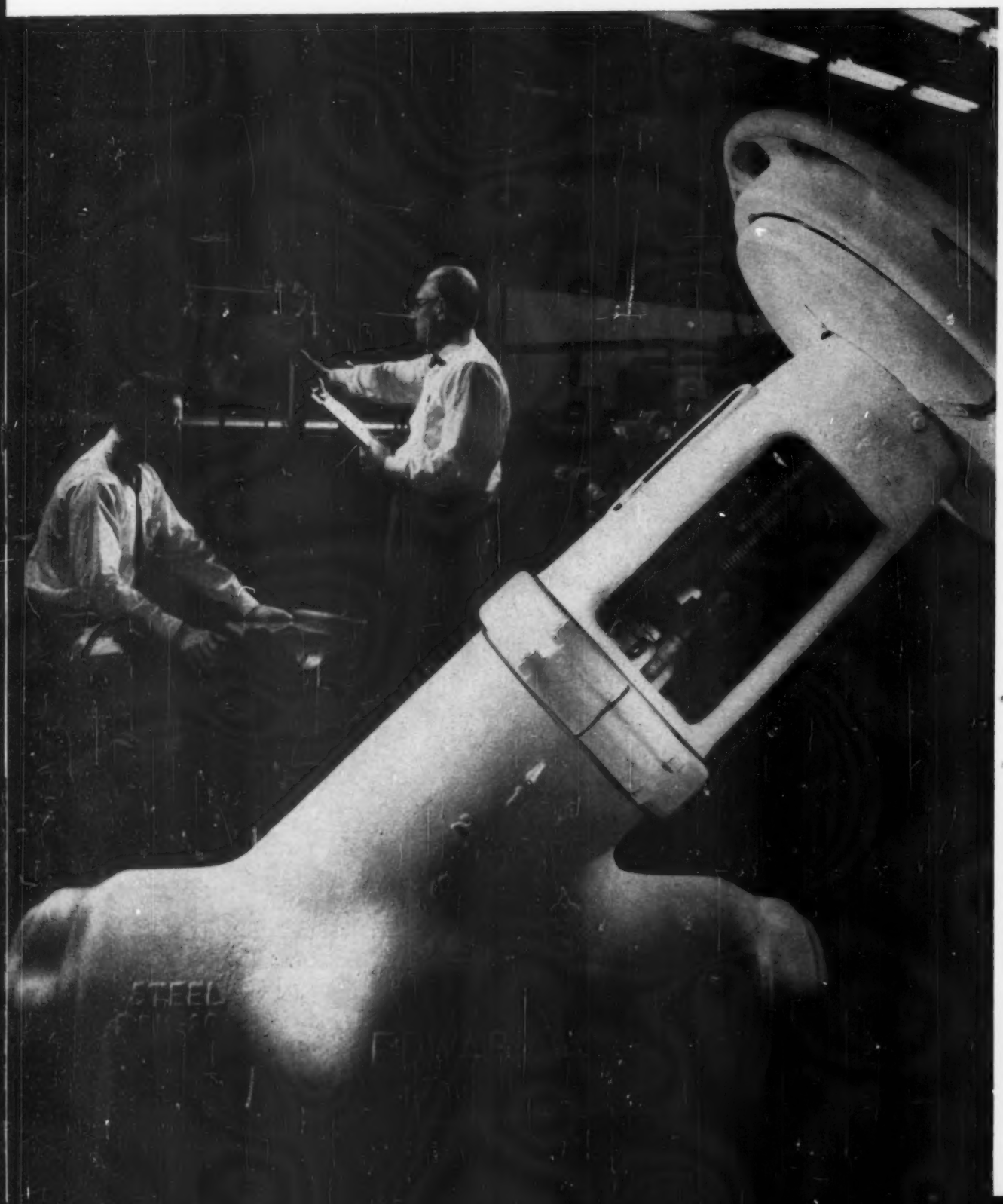
How Edward Valve Research



Reduced Pressure Drop 70%

Power industry advances in unit size created a need for large, high pressure steel valves (ten inch size and larger, 1500 lb class and higher) with three basic qualities: 1. Permanent tight seating; 2. Capacity to handle high flow rates being encountered in new, high pressure plants; 3. Reduced downtime through simplified maintenance. Edward researchers developed the Flite-Flow* design to satisfy that need. This is their story.

In 1951 Edward had already developed large cast steel globe valves with excellent dependability and repairability. Long experience in building inclined stem Y-type valves in small sizes indicated that this configuration offered a more efficient flow path. Edward research engineers set out to learn whether sufficiently strong pressure containing structures might be built in the Y-type design in larger sizes. They also sought to find out if pressure drop could be reduced sufficiently to make such a valve practical for high pressure power plant services.

The project consisted of three steps:

1. INTERNAL CONTOUR DESIGN—Flow tests were conducted with a series of plastic models. Early in the testing program it was observed that flow capacity was not always directly related to the size of the opening. Reduction of turbulence proved to be even more important. This eventually led to subtle internal contour changes to pre-shape the flow before passing through the valve seat. More material was added to certain internal areas to gain additional structural strength.

2. DISK GUIDING TESTS—To compensate for the angular position of the stem-disk assembly tests were conducted to determine whether conventional three-point guiding used in vertical stem Edward valves would be adequate for the inclined stem design. Experiments suggested that four equally spaced guiding surfaces would be superior. This is important in floating disk types such as check or stop-check valves where disk-piston assembly must seat automatically.

3. STRUCTURAL STRENGTH—The usual weakness of a Y-type pressure containing vessel received much attention. Optimum valve contour as determined by flow testing permitted use of a structural member in the flow passage at the downstream side of the seat port. This structural member provides strength exactly where needed without significant increase in pressure drop. Introduction of this segment to the valve body casting without sacrifice in pressure drop was a significant achievement.

RESULTS: This program covered a period of six years. Tests of the completed design were most gratifying. Structural stability, a major problem, was excellent. Strain gage and brittle lacquer tests of finished valve bodies showed stresses well within acceptable limits. Pressure drop reduction amounted to as much as 70 per cent from best previous globe valve experience. Extended tests of finished product at pressures and temperatures above rating showed no operating weaknesses. The Flite-Flow is truly a dependable, repairable, low pressure drop valve.

Edward builds a complete line of forged and cast steel valves from ¼" to 24" for industrial, marine, petroleum and technological services. For more detailed information, contact your Edward Representative, or write Edward Valves, Inc., 1202 West 145th Street, East Chicago, Indiana. Subsidiary of Rockwell Manufacturing Company. Represented in Canada by Lytle Engineering Specialties, Ltd., 438 St. Peter Street, Montreal.

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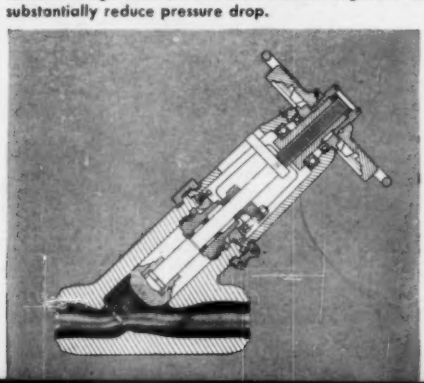
◀ W. G. Lunt, research engineer, and E. B. Pool, chief research engineer, study flow phenomena in plastic half-model of tentative Flite-Flow design.

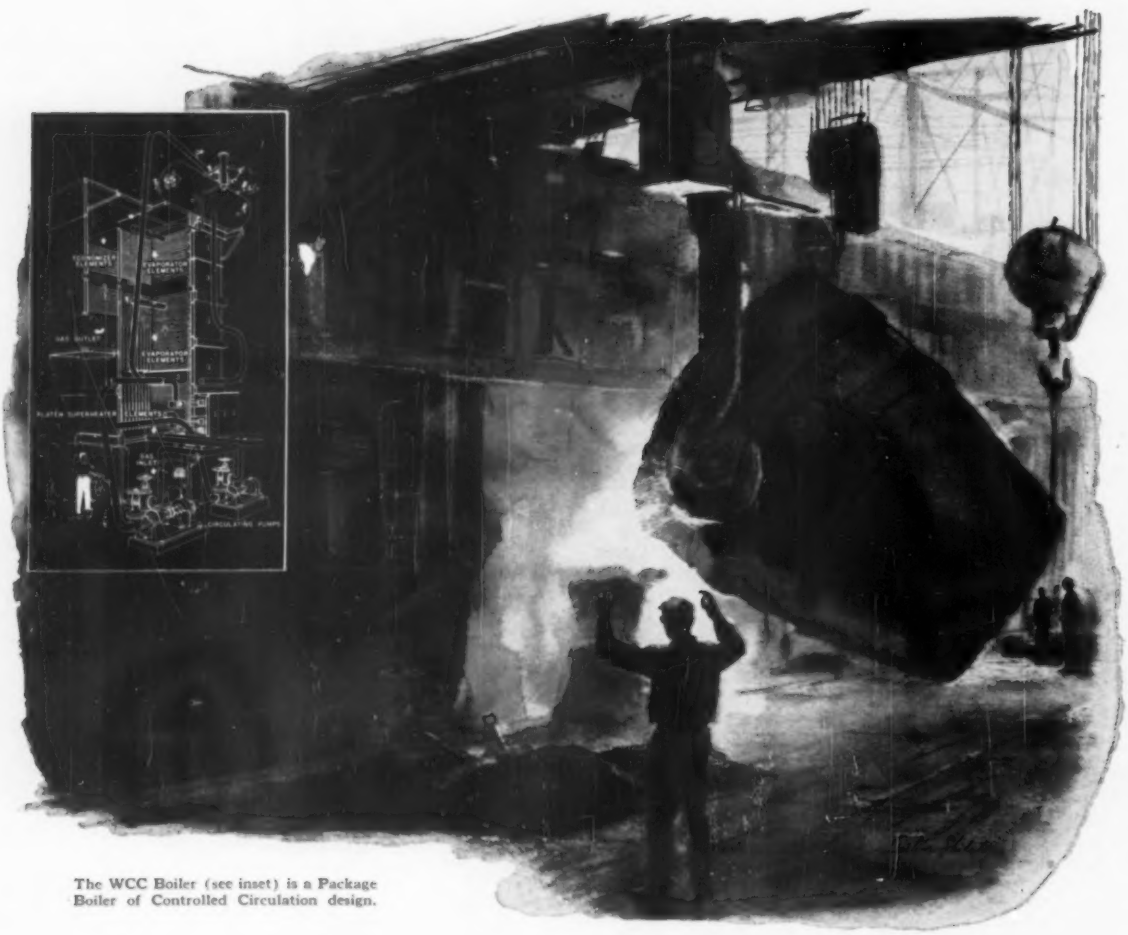
▼ Edward research team lowers experimental valve into test furnace where it is subjected to prolonged extremes of heat and pressure. This was one of the final steps in the development of Flite-Flow valve design.

Cutaway view of Flite-Flow valve showing how inclined stem Y-type valve configuration has been adapted to larger size units for power plant services. This internal contour design enabled Edward research engineers to substantially reduce pressure drop.



WASTE HEAT AND BY-PRODUCT STEAM WHEN

Though no two industrial processes are exactly alike, a great many produce hot waste gases or by-product waste materials. Often, they contain substantial amounts of energy which, when properly used, can provide a valuable addition to the fuel supply of a plant. C-E has had long and varied experience in taming and harnessing many kinds of waste and marginal fuels. At the steel mill pictured below and in refineries like the one at right, C-E boilers use just such fuels to provide dependable, low-cost steam.



The WCC Boiler (see inset) is a Package Boiler of Controlled Circulation design.

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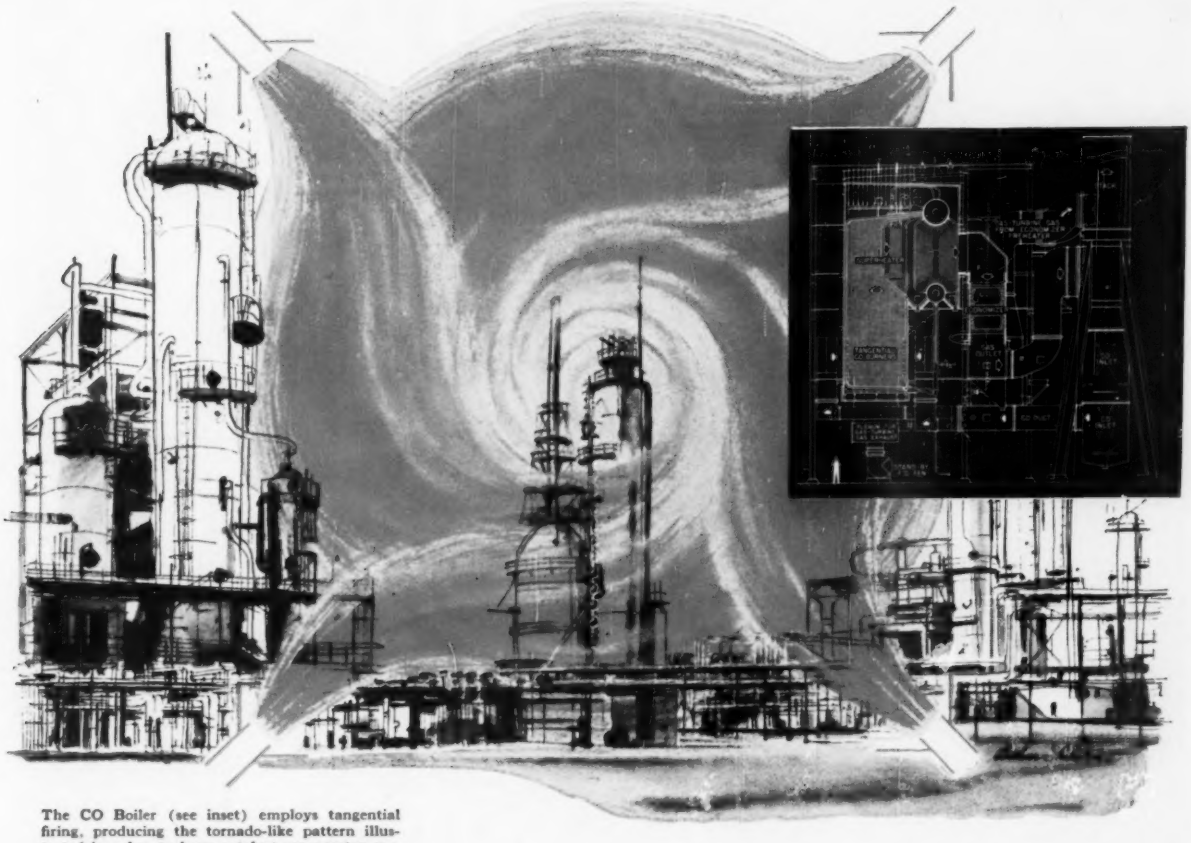

The CO Boiler (see inset) employs tangential firing, producing the tornado-like pattern illustrated in color, to burn catalyst regenerator gas.

As discussed on the opposite page, two interesting examples of waste heat "in harness" are the applications of specially designed C-E boilers to the exhaust of steel mill open hearth furnaces and to the catalyst regenerator exhaust of a refinery. In each case, the gases used are peculiar to the industry involved. In one instance, they are sticky and corrosive and offer only sensible heat. In the other, the gases are toxic and moist, and contain a lean measure of chemical heat in the form of carbon monoxide—in addition to sensible heat. In both cases, C-E advanced engineering has created boiler designs (see sketches) ideally suited to the heat source—boilers which provide maximum steaming capacity with minimum maintenance. Other C-E boiler designs in the waste heat category are in service using a wide variety of waste process gases — with and without chemical heat. In the area of marginal and by-product fuels, C-E has designed and placed in service a large number of boilers which burn such wastes as refinery sludge, wood shavings, sawdust, pith, rice and oat hulls, furfural waste, bagasse, peanut shells, grape skins, spent coffee grounds, black liquor and, of course, coke oven and blast furnace gas.

What all this adds up to is the fact that there is really no such thing as waste heat—there is only *wasted* heat. And there needn't be—because Combustion has the know-how and experience to put almost any potential energy source to work for you—to provide you with an extra dividend in the form of additional low-cost steam for your plant. Why not investigate harnessing a C-E boiler to your waste heat or by-product material? The amount of money it can save for you may be surprising.

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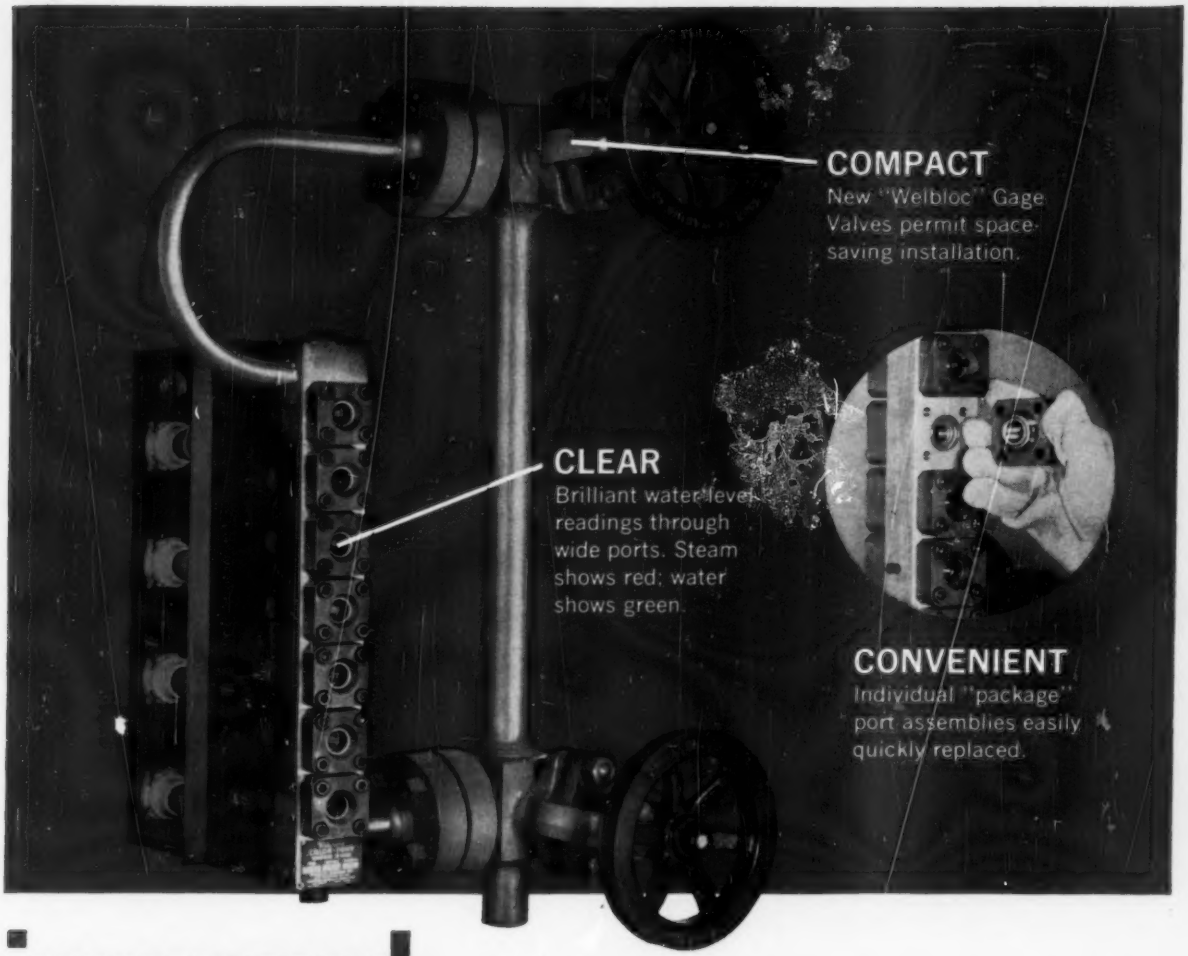
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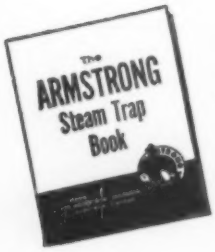

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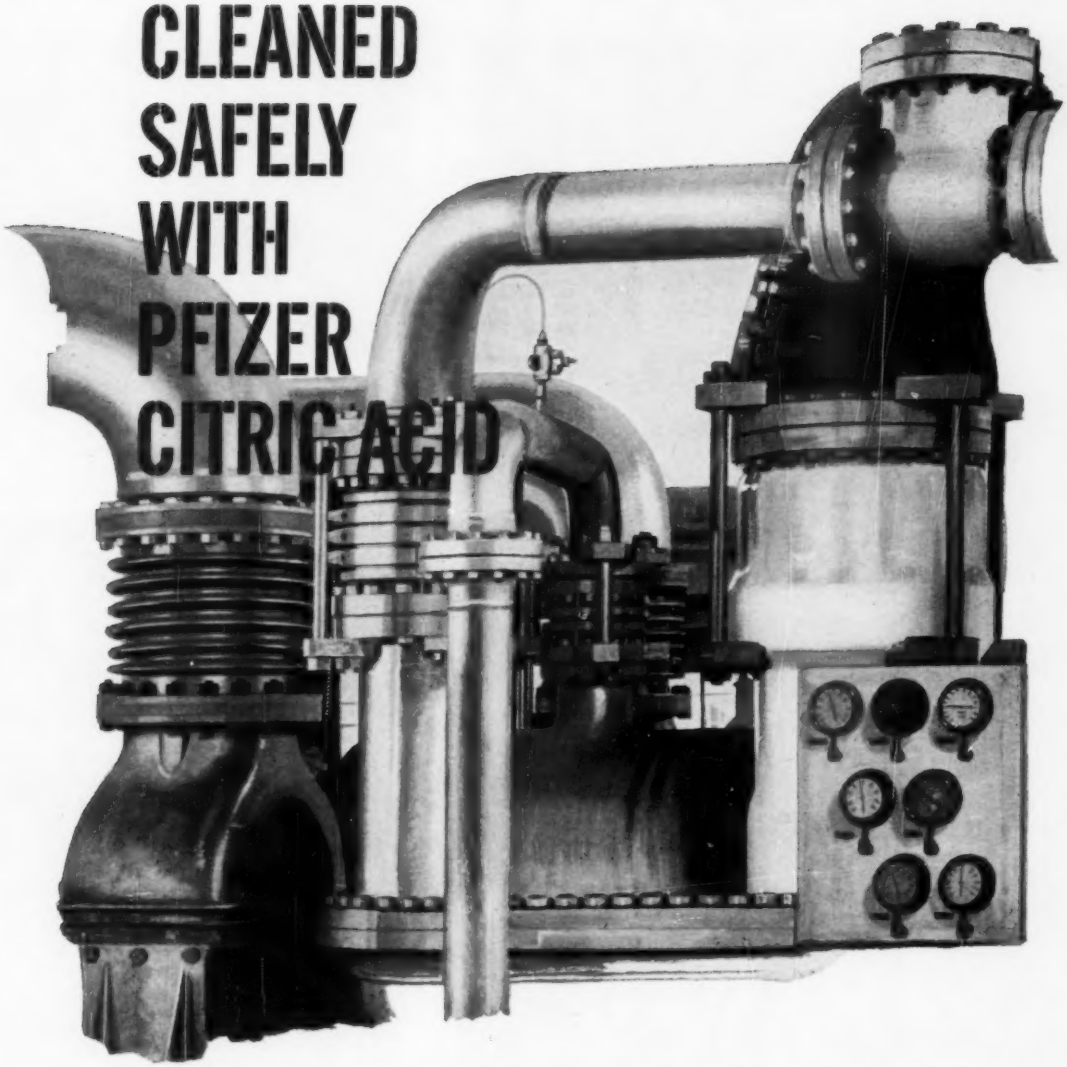

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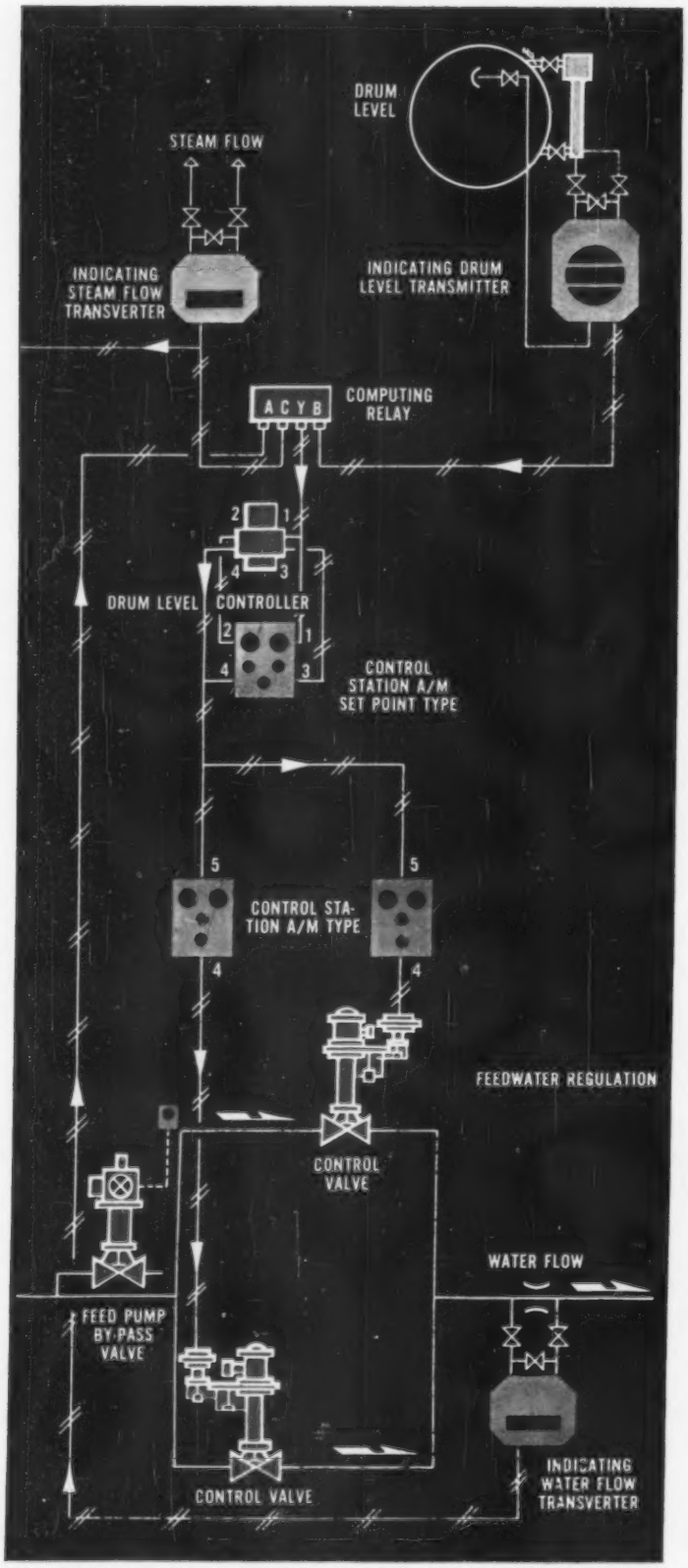
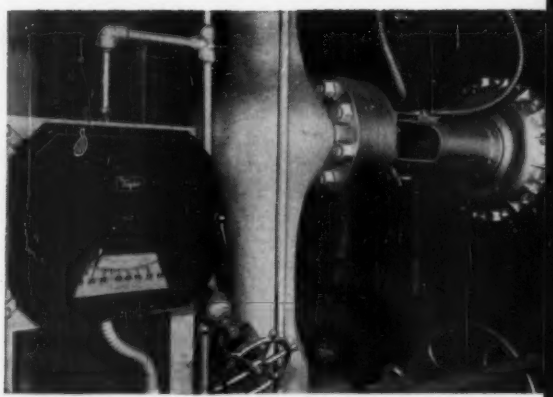
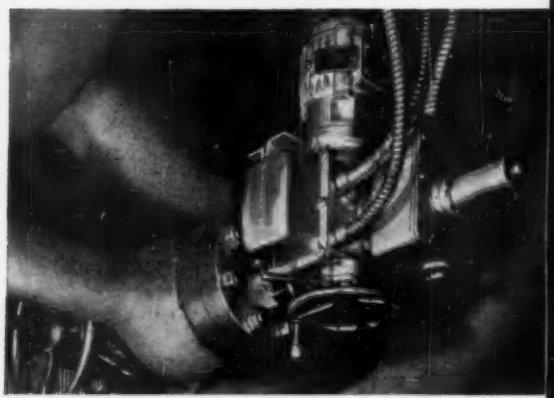


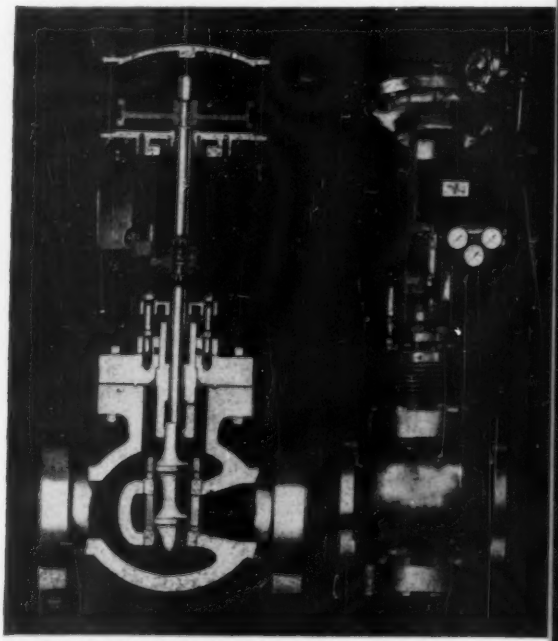
Three influence feedwater regulation is just part of a complete Copes-Vulcan boiler control system installed at a pace-setting utility station. Feed to boiler is modulated by steam flow, feedwater flow, and drum water level.



Copes-Vulcan recirculation control protects boiler feed pumps. When pump discharge falls below a certain level, a diaphragm-operated by-pass valve opens to assure sufficient flow to prevent overheating of the pump.



A feedwater and heater by-pass valve is shown above. Also, a Copes-Vulcan control valve is installed in each of the two main boiler feed lines. These valves handle pressure drops of over 2600 psig without difficulty.



Versatile control valves feature simplicity of design. Piston-type CV-P (left) is ideal for high-duty service. Diaphragm-type CV-D (right) is designed for remote control service. All Copes-Vulcan valves are tailored to the job.

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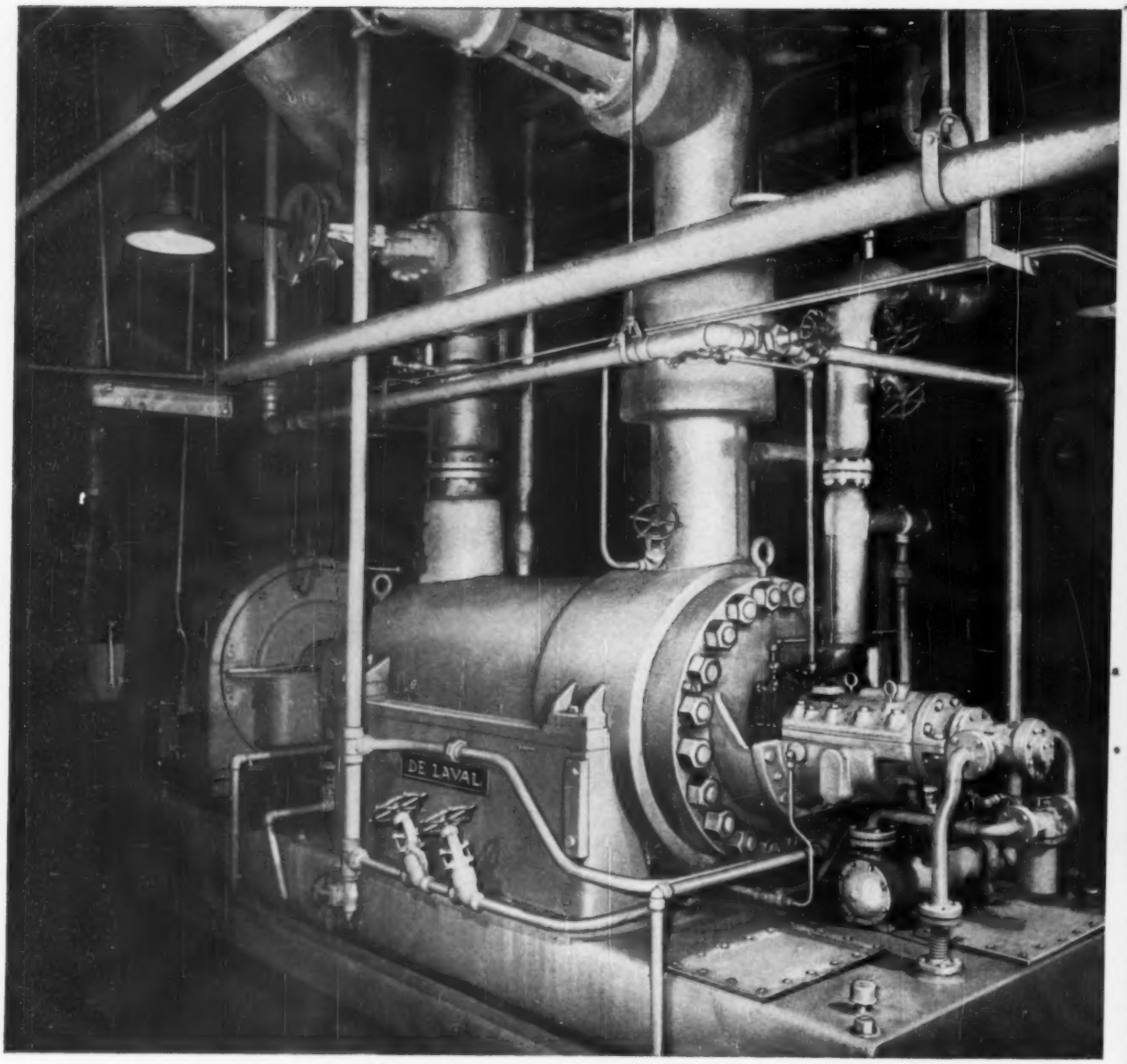

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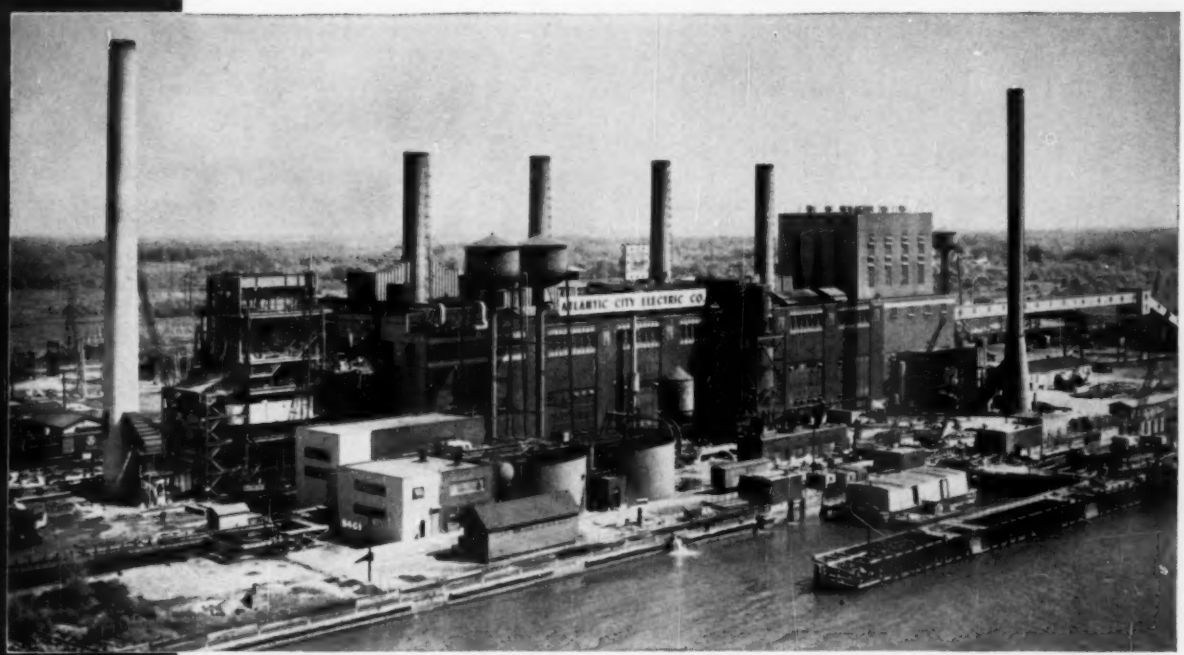
at Atlantic City Electric

Gibbs & Hill, Inc., Consulting Engineers, handled project for new 79,000 KW unit

To meet increased load demand while improving station performance, Atlantic City Electric has completed the installation of a new 79,000 KW No. 1 main unit at Deepwater Station, the largest now operating in their system.

Providing dependable boiler feed service are two 1000 HP direct motor driven half capacity De Laval barrel feed pumps, now in their second year of operation. This is the second modern installation at Deepwater to be served by De Laval barrel pumps.



Deepwater Station at the southern extremity of the N. J. Turnpike.

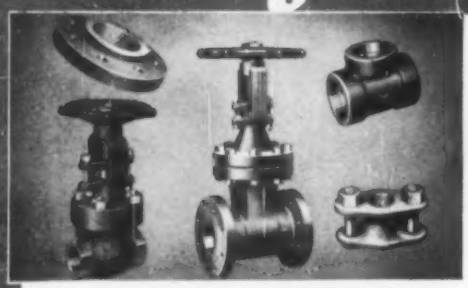
DE LAVAL STEAM TURBINE COMPANY
816 NOTTINGHAM WAY, TRENTON 2, N. J.

DL 236

For more data circle 517 on Post Card

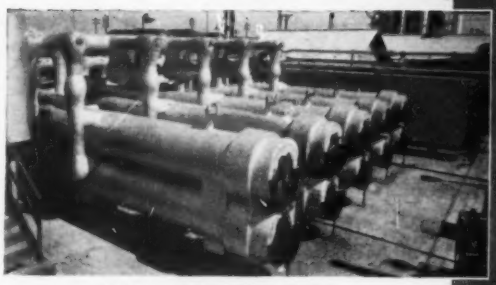
Vogt PRODUCTS

Designed for today's Tough service demands



FORGED STEEL VALVES & FITTINGS FOR TOUGHNESS AND TROUBLE-FREE SERVICE

Forged from carbon and alloy steels, Vogt valves, fittings, flanges and unions are built to safely handle liquids and gases at high pressures and temperatures in the modern petroleum refinery and petro-chemical plants. The complete line includes flanged, screwed and socket weld end globe, gate and check valves—ells, tees and crosses—couplings—bushings—plugs—unions—flanges and flange unions—and weld caps.

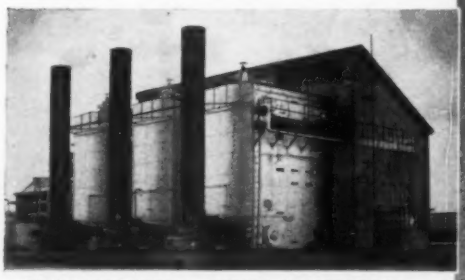


PROCESS EQUIPMENT FOR EVERY SERVICE

Vogt constructs process equipment in wide variety to all Codes. Stills and towers, oil chillers, crystallizers, heat exchangers, molding machines, etc., serve in the manufacture of oils, greases, 100 octane gasoline, synthetic rubber, chemicals and related products around the world.

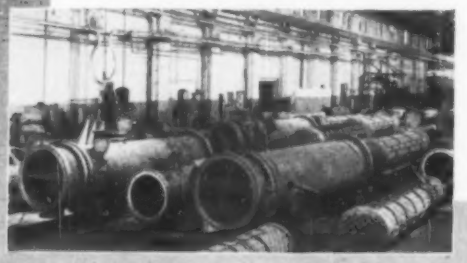
MORE REFRIGERATION TONNAGE AT LESS COST

More than 70 years of engineering and manufacturing experience is incorporated in Vogt refrigerating and ice making equipment. Compression Systems and Tube-Ice Machines in a wide range of capacities serve industrial and processing plants and institutions here and abroad.



HIGH EFFICIENCY STEAM GENERATORS

Vogt steam generators are designed to give maximum rating in a minimum of space, with high efficiency and low maintenance expense. Bent tube and straight tube designs are available for solid, liquid or gaseous fuels to meet every power, process or heating requirement.



SPECIAL MATERIALS COMBAT CORROSION AND PRODUCT CONTAMINATION

Our modern shops produce a wide variety of equipment from special metals and alloys to fight corrosion and product discoloration or contamination. Fabrication procedures insure that corrosion resistant properties of welds will match that of the materials used to construct the equipment.

HENRY VOGT MACHINE CO., LOUISVILLE, KY.

SALES OFFICES:
New York, Chicago, Cleveland, Dallas, Camden, N. J.,
St. Louis, Charleston, W. Va., Cincinnati

PRODUCTS FOR REFINERIES, CHEMICAL PLANTS, POWER PLANTS AND PROCESS INDUSTRIES
Write for literature, Dept. 24A-GPE

For more data circle 518 on Post Card

how to choose the right colorimetric analyzer

CRITICAL process decisions must often wait hours upon the result of a trip to the laboratory for a wet analysis. But for those determinations that can be performed colorimetrically, continuous, automatic endpoint analysis can now be performed right on the plant floor. New Milton Roy instruments continuously run through every step of a wet analysis in the parts-per-million—even parts-per-billion range without supervision. And any colorimetric analysis that fits these basic requirements can be automated:

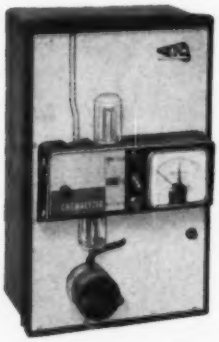
1. No more than four reagents required.
2. All interfering ions can be eliminated.
3. No heating, filtering, extracting, or decanting needed.
4. Clean and clear samples and reagents.

"A completely automatic quantitative analysis lab" describes Quantichem colorimetric analyzers. The unit illustrated above analyzes silica in parts-per-billion concentration, safeguarding boiler and turbine at a major electric generating utility.

When to use the Quantichem* analyzer

Extremely sensitive Quantichem analyzers measure concentrations in parts-per-billion (ppb) ranges with accuracy approaching ± 3% of full scale, and sensitivity of ± 1% of full scale. Typical determinations include soluble silica (0-50 ppb), dissolved oxygen (0-30 ppb), copper, soluble iron, hydrazine, and others requiring up to four chemical reagents.

A dual beam optical system and the use of two sample cells (one as a reference cell) eliminate all possibility of errors in measurement due to physical interference with the light path, different phototube aging characteristics, sample turbidity, sample color, and dirt on cell windows.



All the benefits of single-reagent automatic colorimetric analysis are provided by the simple, compact and inexpensive Chemalyzer analyzer. Recording is optional with this unit.

Unique Minus Delta P* metering pumps, housed in the analyzer, meter up to four reagents with accuracies within ± 0.25%.

Standard designs include a built-in limit alarm and circular or strip chart recorder with single or multiple recorders. As many as eight different samples can be sequenced through a single analyzer, with the analysis of each recorded on an eight-point strip chart recorder. Individually adjustable limit alarms are also available for each of the multiple samples.

Write for Bulletin 1156-1

When to use the Chemalyzer* analyzer

The Chemalyzer unit is designed for simple colorimetric analyses requiring a single reagent, such as water hardness, residual chlorine and phosphates. A simple inexpensive unit, it has no reference cell, and therefore requires samples free of turbidity and discoloration. Though there is no amplification of the measurement signal, concentrations of impurities are detectable to the parts per million range.

One typical application for Chemalyzer instruments is monitoring effluent from zeolite softeners for hardness. At three or six minute intervals (as specified) a fresh sample of effluent is analyzed, and the ppm concentration of hardness is indicated on the face of the instrument. An optional feature is a high limit relay and switch to energize a red light whenever hardness concentration exceeds a pre-set limit. If recording is desired, a potentiometric type recorder with sensitivities of 10-60 mv may be wired quickly to recorder terminals inside the cabinet.

The Chemalyzer is compact, easy to operate, and can be installed in minutes. It operates practically maintenance-free. All parts in contact with reagents are made of suitable corrosion resistant materials.

Write for Bulletin 858-1

How to control with Milton Roy analyzers

The high limit switch available in either instrument can be used to initiate control action directly or through relays. Typical functions include starting or stopping a controlled volume pump and starting an automatic regeneration cycle on a zeolite softener. Through the use of a proportional slidewire in the recorder, the Quantichem analyzer can automatically vary the capacity of a controlled volume pump, to increase or decrease the amount of chemical needed by the process.

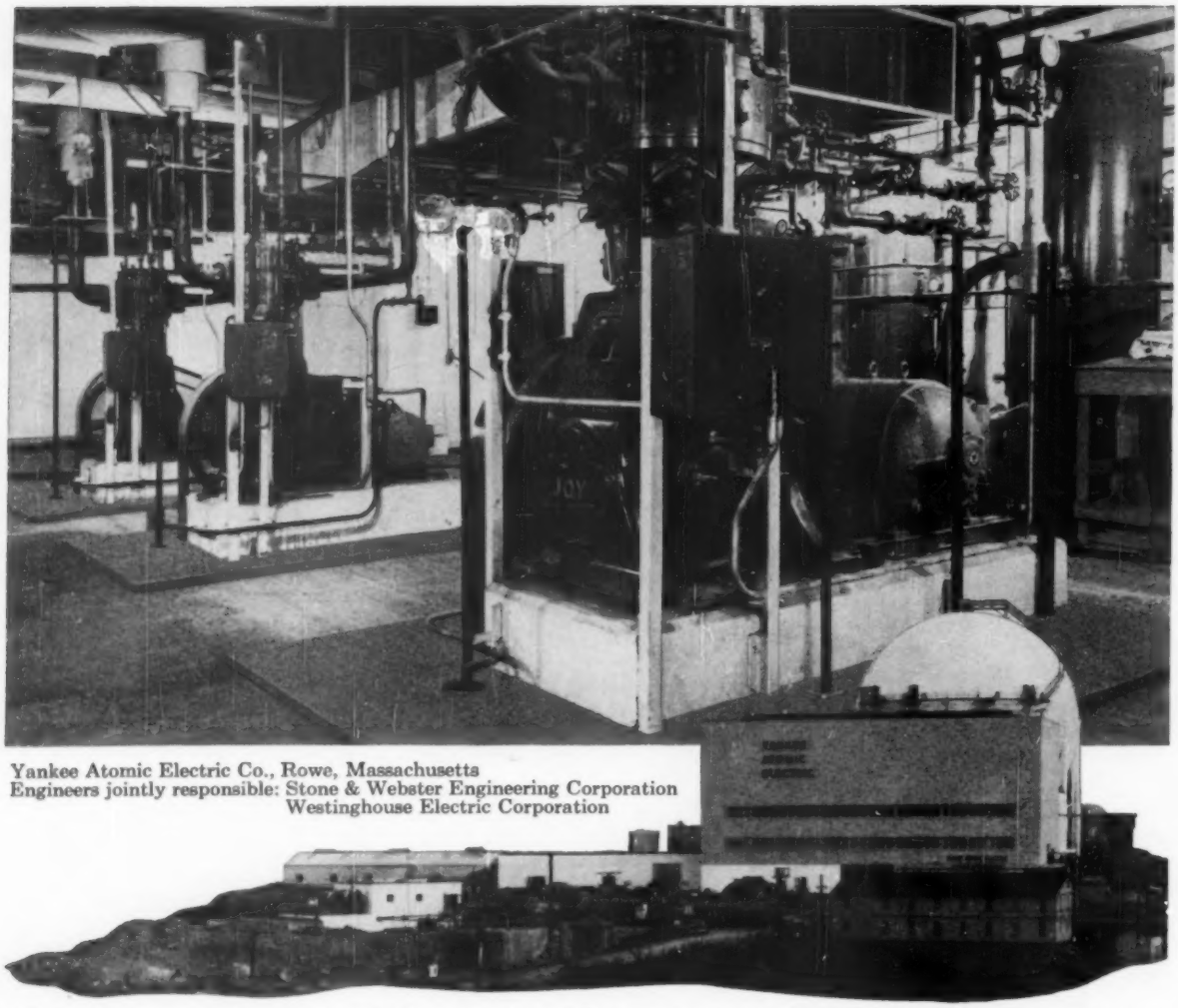
Write for complete data. Milton Roy Company, 1300 East Mermaid Lane, Philadelphia 18, Pennsylvania.

milton Roy
CHEMICAL INSTRUMENTATION SYSTEMS

Controlled Volume Pumps • Quantichem Analyzers
Chemical Feed Systems • pH Instruments

*Tradename of Milton Roy Co., Phila., Pa.

For more data circle 519 on Post Card



Yankee Atomic Electric Co., Rowe, Massachusetts
Engineers jointly responsible: Stone & Webster Engineering Corporation
Westinghouse Electric Corporation

Yankee Atomic Electric chooses JOY Compressors for New England's first Nuclear Power Plant

Compressed air requirements at the Yankee Atomic Electric plant are not large but vitally important. Reliability of all machinery is a must, once the reactor goes critical. Two Joy WGO-9 vertical compressors supply oil-free air for instruments and controls. Each machine produces 172 cfm at 100 psi and is V-belt driven by a 25 horsepower motor. Carbon graphite piston rings completely eliminate lubricating oil in the cylinders. The compact vertical design requires less than seven square feet of floor space for each installation.

General service air is supplied by a 100 hp Joy WG-9H compressor producing 769 cfm at 100 psi. This machine has the same space-saving vertical design in sizes up to 150 hp.

Joy compressors are chosen for many of the country's finest installations . . . there is a size and type for you, reciprocating, centrifugal or axial. For information, write for bulletin 1685-56C.

AIR MOVING EQUIPMENT FOR ALL INDUSTRY

JOY

Joy Manufacturing Company
Oliver Building, Pittsburgh 22, Pa.

In Canada: Joy Manufacturing Company (Canada) Limited, Galt, Ontario

For more data circle 520 on Post Card

Current Catalogs

Engines and Turbines

101 Industrial Gas Turbines — Advantages and economies of industrial gas engines made by Orenda Engines Ltd. for general industrial and other applications are outlined in this 24-pp bulletin. Performance data and curves, dimensions, operating costs curves, heat recovery data and other information included.

102 Industrial Gas Turbines — Versatility of General Electric Co.'s gas turbines as a power source for a variety of industrial and other applications, including power for emergency generator sets, is detailed in 16-pp Bulletin GED-5685. Includes review of engine specifications.

103 Single Shaft Gas Turbines — Features of single shaft gas turbines designed for mechanical and generator drive are outlined in 6-pp Bulletin 186 by Clark Bros. Co., Div. Dresser Industries, Inc. Includes cutaway cross-section showing component details, as well as table of dimensions and specifications, materials of construction.

104 Uninterrupted Power — Eight-pp Bulletin P-2, Consolidated Diesel Electric Corp. contains detailed information on uninterrupted power supplies capable of providing continuous power in event normal power sources fail. Illustrates and describes operating features and reproduces oscillographic recording of performance under various conditions of power interruption.

105 Pneumatic Engine Control — Featured in Folder SF-760 are pneumatic engine control systems designed by Robertshaw-Fulton Controls Co. for gas engine compressors in pipelines and for industrial diesel engine industrial installations. Advantages are detailed and typical operation described.

Pumps, Compressors

106 Versatile Pump — Six-pp Bulletin P10-B46 describes operation and applications of Western Machinery Co.'s clog-free Torque-Flow pump. Typical applications in sewage treatment, slurry handling, chemical processing, suction lift and air handling, and other applications are illustrated.

107 Handbook on Pumps — Engineering Manual EM-611, issued by Marlow Pumps, Div., Bell & Gossett Co., contains 42 pp of comprehensive data on pumps and pumping. Defines common pump terms, and includes friction loss data, capacity and volume equivalents, decimal equivalents, horsepower requirements, installation details, viscosity and specific gravity table, and other engineering data needed in pump selection.

108 Packaged Compressor Systems — High pressure packaged compressor systems for air or gas are illustrated and described by Clark Bros. Co. in 8-pp Bulletin 189. Design and construction features are detailed and photos and cutaway diagrams showing component details of compressor systems are included.

Mechanical Power Transmission

109 Shaft, Flange Mounted Drives — Design and construction advantages of shaft and flange mounted drives made by The Falk Corp. are detailed in 36-pp Bulletin 7100. Operation and selection information is included along with dimensional data and diagrams and photos of application possibilities.

110 Shaft Mounted Reducers — Features and advantages of a shaft-mounted rotating transmission are described by Airborne Accessories Corp. in 8-pp Bulletin IR-60. Provides charts, tables, diagrams and cutaway drawings showing design and construction details.

111 Cast-Tooth Sprockets — Stock sizes of cast-tooth sprockets available from Link-Belt Co. are listed in 12-pp Book 2867. Lists types and sizes of cast-tooth sprockets, including arm center, plate center, segmental and split rim sprockets and traction wheels, and includes detailed selection tables.

112 Heavy Duty Couplings — Twelve-pp Catalog 70 of Ajax Flexible Coupling Co., Inc., contains engineering, application, capacity and dimensional data on dihederal spindle shaft couplings for use on mills and allied equipment throughout the ferrous and non-ferrous metal, paper, rubber, chemical, food industries.

113 Belting Selector — Specifications and other information on conveyor, elevator and transmission belting manufactured by Boston Woven Hose & Rubber Div., American Biltrite Rubber Co., are presented in this 36-pp product bulletin. Tables give belt weights, gages, fabrics, and belt recommendations.

Refractories

114 Controlled Refractories — This 8-pp brochure by Harbison-Walker Refractories Co. reviews controlled fireclay refractories for medium-duty service, high-duty service and super-duty service. Gives property descriptions, various test results and lists typical applications.

115 Refractory Data — Properties and applications of refractories are detailed in this 16-pp illustrated brochure of Harbison-Walker Refractories Co. Describes refractory raw materials, control testing, mining, blasting and batching of raw materials through molding and firing of refractory brick.

Electrical

116 Motor with Embedded Windings — Eight-pp Bulletin 6100 describes design features, performance characteristics and size range of The Lincoln Electric Co.'s squirrel cage induction motors with Multiguard stator encapsulation. Mechanical features are also described.

117 Squirrel Cage Induction Motors — Twelve-pp Bulletin 600, Century Electric Co., describes squirrel cage induction motors in basic drip-proof designs. Outlines motor applications, performance characteristics, mechanical design variations, construction details, insulation details, ratings and dimensions.

118 Substation Planning — Described in Bulletin 61B9695 is a minimum investment approach to substation planning with Allis-Chalmers Mfg. Co.'s Regu/Tran unit assembly which allows power transformer to be installed first, load tap changing later. Advantages of this system are detailed.

New and revised publications reviewed on these pages offer help on operating and maintenance problems. To order, use the handy Reader Service Cards provided on pages 85 and 86.

119 Dry Type Transformers — Ventilated dry type transformers made by Niagara Transformer Corp. are featured in 8-pp Bulletin 160. Describes insulation, core and coil construction, and includes specifications, dimensional drawings and sound level charts.

120 Packaged Busway — Construction features of H. K. Porter Co.'s 100-amp compact packaged busway for lighting and power distribution are detailed in 10-pp Form 698. Describes advantages and applications and contains dimensional data, voltage drop curve.

121 Basic Protection — Ten-pp Bulletin BPB issued by Bussmann Mfg. Div., McGraw-Edison Co. gives information on motor protection, system selectivity to faults, fuse application and fuse selection. Tells how to coordinate opening time of protective device so that a fault current will be isolated to the circuit of origin and includes charts showing time of opening and current limitation.

122 Control Center — Bulletin GED-4152 gives latest developments on General Electric Co.'s control center with grouped control for independent or coordinated units. Describes advantages of design, installation, maintenance.

123 Fuse Panels, Switches — Twenty-pp Publication PL 12-29-660, The Clark Controller Co., gives installation and application data on fuse panels, service entrance equipment, general-purpose switches, general toggle switches, safety switches, and double-throw switches. Engineering data section gives allowable current-carrying capacities, number of conductors in conduit or tubing, and load and circuit chart.

124 Oil Circuit Reclosers — Electronically controlled oil circuit reclosers are featured in 16-pp Bulletin CR1WE issued by Line Material Industries, McGraw-Edison Co. Includes application, design features, operation details, specifications and dimensional information.

125 Switches and Devices — Catalog 60 presents Wadsworth Electric Mfg. Co.'s fusible and circuit breaker devices. It contains over 200 pp of engineering

information on construction, materials, dimensions, knockouts and weights on fusible and not-fusible safety switches, double throw safety switches, general duty switches, service equipment, circuit panels, circuit breakers, circuit breaker load centers, and other devices.

126 Color-Coded Buttons — Design information on The Clark Controller Co.'s color-coded push-button stations and controls is presented in 8-pp Publication PL 100-1-960. Described are push button units, selector switch units, standard pilot lights, and push-to-test pilot lights or lighted push buttons.

Construction

127 Floor Gratings — Three basic types of floor grating construction — all-weld, riveted and pressure locked — are illustrated and described in this 16-pp product bulletin of Borden Metal Products Co. Includes dimensional drawings, safe load tables and selection details.

128 Structural Assemblers — Described in Form RD-1 are assemblers made by Unistrut Products Co. for use with rods, tubes and pipes, for framing of high strength structures and for making precision fixtures and assemblies without welding, casting or machining. Applications are illustrated, and specifications included.

Heaters, Heating

129 Industrial Heaters —Illustrated and described in this 12-pp bulletin by Lennox Industries Inc. are industrial heaters for unit heater or central applications. Typical installations are pictured, construction and operating features shown on cutaway and engineering data and specifications included.

130 Storage Water Heaters — Detailed information on vertical and horizontal storage water heaters is presented in 8-pp Bulletin 61 released by Niagara Weldments Inc. Describes construction of tanks and elements, alloys available for special fabrications, various clads and linings available to extend tank life, and includes selection data.

131 Liquid Phase Heater — Features and advantages of Vapor Heating Corp.'s liquid phase heater are detailed in 8-pp Bulletin 4023. Typical applications are listed along with facts about hot oil systems and complete specifications.

132 Heat Transfer Equipment — Bulletin 800 summarizes heat transfer equipment of Brown Fintube Co. including double pipe heat exchangers, fired indirect heaters, tank heaters, tank suction and line heaters, process heaters and coolers, gas cooling and heating equipment, and custom built equipment.

Waste Handling

133 Incinerator Selector — This handy slide rule device offered by Morse Boulger, Inc. is designed to simplify selection of correct incinerators for various types of installations. A slide is moved to the type of installation and the appropriate variable factor, and the recommended incinerator appears in a window opposite the number of hours of operation.

134 Choosing an Incinerator — Eight-pp Bulletin 185 of Morse Boulger, Inc. pictures a variety of incinerators. Provides data on average weight of various types of waste, content of various waste containers, recommended maximum load allowances for different types of buildings, dimensions and capacities, size of stack required, and weight of incinerator unit. Tells types of waste each incinerator is designed to burn.

135 Heavy Duty Incinerators — Smokeless-odorless incinerators for heavy-duty use in commercial and industrial installations are illustrated and described by The Winnen Incinerator Co. in this colored catalog. It covers custom-built models, portable (standard) models and prefabricated chimneys, with complete specifications.

Piping and Valves

136 Clay Pipe and Fittings — Illustrated and described in 40-pp Bulletin E-360-53 is Evans Pipe Co.'s standard strength, extra strength, perforated, and double-length vitrified clay pipe, clay pipe with plastisol double-ball joint, clay fittings and other clay products. Tables of sizes and dimensions are included.

137 Pipe Fitters Manual — Information expected to be at the finger tips of pipe fitters and pipe welders is concentrated into this 72-pp fitters manual offered by Tube Turns Div., Chemetron Corp. Text, tables and illustrations in the pocket-size handbook give important mathematical, physical, chemical and metallurgical data and related design, layout and mechanical information.

138 Lubricated Plug Valves — Function and properties of lubricants and selection of lubricants for lubricated plug valves are fully covered in this 12-pp lubricating manual issued by Walworth Co. General specifications and a lubricant selection chart are included.

Seals

139 Elastomeric Seals — This 12-pp bulletin describes a line of elastomeric seals called Tetraseals designed by Goshen Rubber Co., Inc., to seal across two opposite faces of a rectangle. Applications are detailed and dimensional data tabulated.

140 Rotary Gland — Featured in Bulletin TC154/5706 issued by Bestobell (Canada) Ltd. is a line of glands for centrifugal pumps designed to overcome rotary sealing problems. Advantages of gland are detailed.

Instruments and Controls

141 Recorders, Indicators — Design and construction features of Minneapolis-Honeywell Regulator Co.'s strip chart and circular chart recorders are illustrated and described in 48-pp Catalog C 15-1a. Detailed specifications and dimensional data are included along with tables of scale ranges, details on measuring elements.

142 Electric, Electronic Controls — Applications of electric and electronic controls in commercial and industrial air conditioning installations are described in Barber-Colman Co.'s 18-pp Electronic Handbook. Theory of electric and electronic controls is explained, illustrated with photos and diagrams, and various control systems are covered.

143 Transistorized Controls — Transistor circuits and thermistor sensing elements are among features of Fenwal Inc.'s temperature controls described in 8-pp Bulletin MC-190. Detailed specifications and sketches of application arrangements are included.

144 Infrared Pyrometers — Industrial infrared radiation pyrometers for permanent installation or portable use are described in Technical Bulletin TB 1372 issued by Servo Corp. of America. Detailed specifications are included.

145 Boiler Level Controls — Basic principles of boiler water level controls detailed in 16-pp Catalog Section 3 by Magnetrol, Inc. Illustrates and describes major design features and includes installation dimensions and diagrams.

146 Blast Furnace Controls — Application of automatic control systems to 11 areas of blast furnace operations is described in 24-pp Bulletin MSA-190 released by Hagan Chemicals & Controls, Inc. Charts, diagrams and photos of both electronic and pneumatic systems are included.

Slings, Wire Rope

147 Chain Slings, Connectors — Specifications and working load limits for alloy chain slings, rings, links and hooks are presented in this 16-pp product bulletin of Jones & Laughlin Steel Corp. Advantages and safety features are detailed, and data on use, maintenance, inspection are included.

148 Wire Rope Slings — Detailed information on wire rope slings made by The Colorado Fuel and Iron Corp. is presented in this 84-pp product catalog. Each major type of sling is described, complete with illustrations and charts, and selection details and basic rules of hitching included.

149 How to Use Wire Rope — Comprehensive information on use and abuse of wire rope is presented in this pocket-size 92-pp manual offered by Macwhyte Wire Rope Co. Covers selection of wire rope, constructions, capacities, maintenance and lubrication, breaking-in of wire rope, approved methods of seizing wire rope, wire rope attachments, attaching sockets, and includes useful decimal equivalents, wire gages, metric system units, and glossary.

Boilers, Auxiliaries

150 Steam Generators — Automatic packaged steam generators manufactured by Ames Iron Works, Inc. are featured in 18-pp Bulletin AA 2760. Analysis of boiler design factors is included along with detailed performance data, photos and a longitudinal section showing components.

151 Pressure Vessel Code — The purpose of this reference guide to ASME boiler and pressure vessel code issued by Missouri Boiler & Tank Co. is to illustrate some of the types of pressure vessel construction provided for under Section VIII of ASME Code, and to furnish direct references to rules that apply to these construction features. Comes in handy wall-chart form.

152 Manual Soot Blowers — Illustrated and described by Copes Vulcan Div., Blaw-Knox Co. in Bulletin 1071 is a

Continued on page 85

NEW FROM AMERICAN-STANDARD INDUSTRIAL DIVISION

Power-Lift† for power plants

through better design in surface condensers

Power-Lift is a timely new concept of coordinated products and services from American-Standard Industrial Division. Its purpose is to help you raise overall efficiency by offering products that are proved in the field—and designed, engineered, and manufactured to a uniform standard of quality and performance. American-Standard surface condensers, for example, have been continuously improved by development, research, and field experience over more than four decades. To see how their design improvements can benefit your plant operations . . .

†Service-mark of American Radiator & Standard Sanitary Corporation

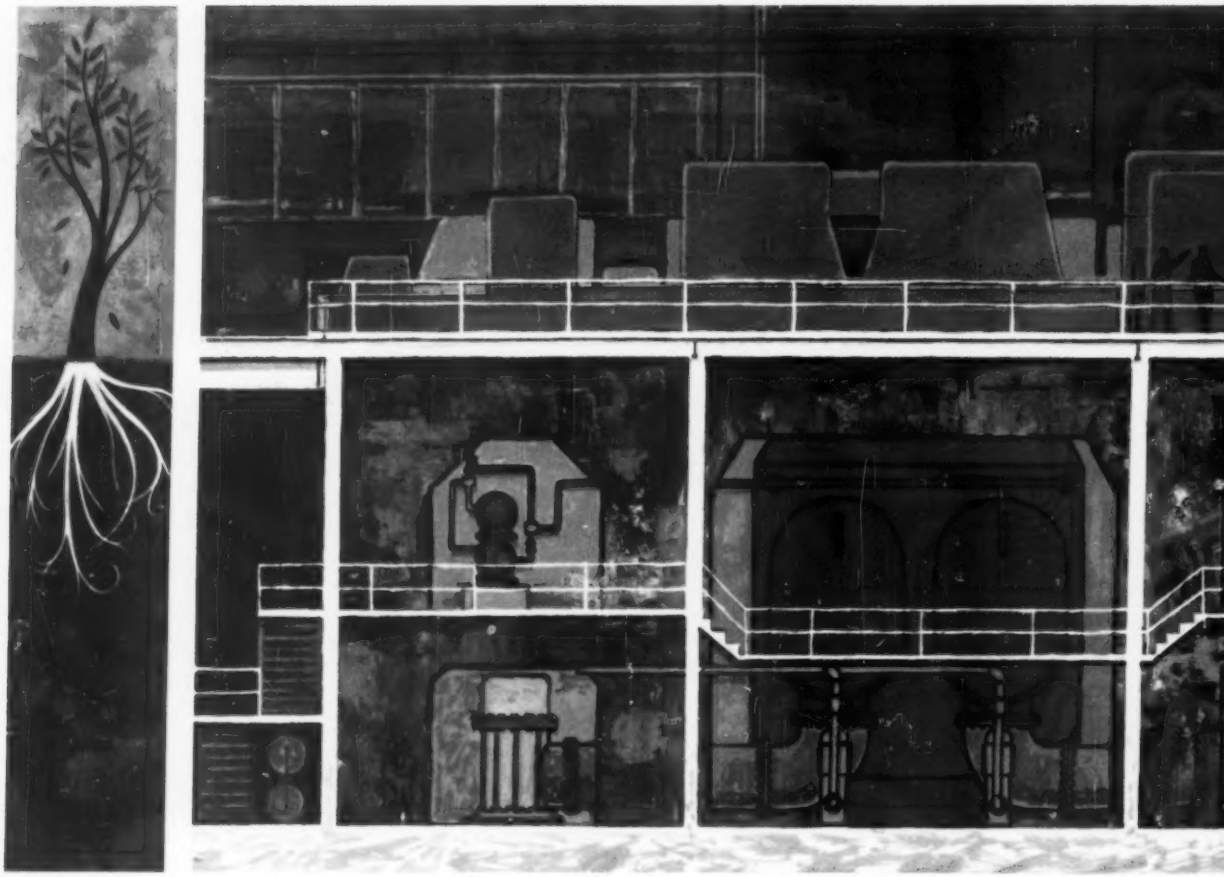
lift the flap

American-Standard Industrial Division POWER-LIFT IN ACTION

surface con

WITH TOMORROW'S DESIGN IMPROVEMENTS TODAY

For the plant in your future you can plan with confidence using American-Standard surface condensers of today. They've made remarkable records of long, trouble-free life in producing design vacuum, zero degree depression hotwell temperature, and complete deaeration over a range of operating conditions—a result of many design improvements

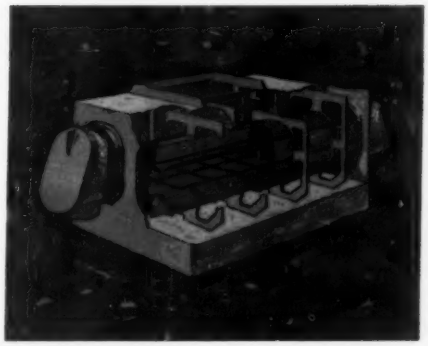


Copyright 1960, American Radiator & Standard Sanitary Corporation

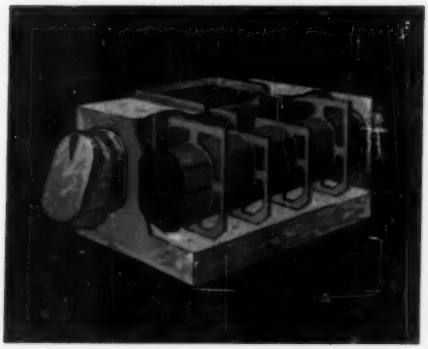
ndensers

and engineering features: Short steam path through tube bundle and improved steam distribution reduce pressure drop and assure top condensing efficiency of all tube surface. Pressurizing steam scoop traps inlet steam for deaerating hotwell. Hotwell deaerating trays further scrub condensate, completing deaeration and producing hotter feedwater. And new advance-design features reduce erection cost up to 65% over conventional methods.

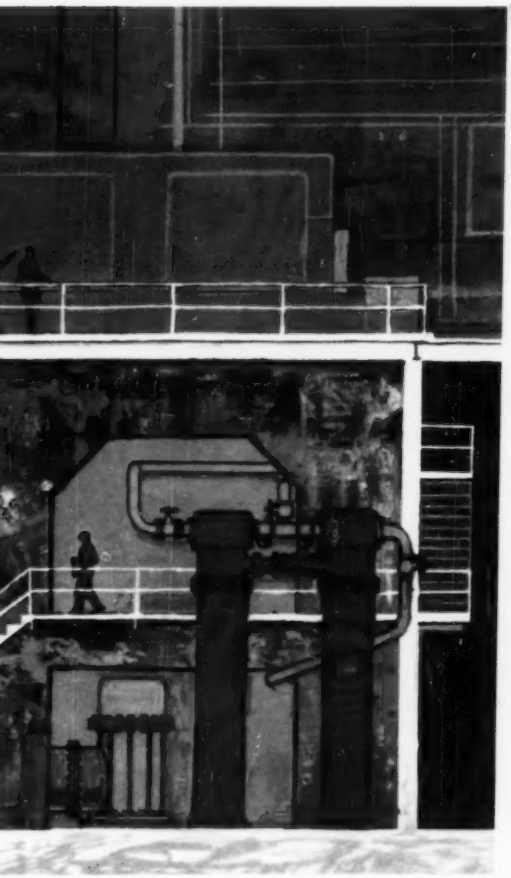
Moisture impingement grids extend tube life, and assure even distribution of steam.

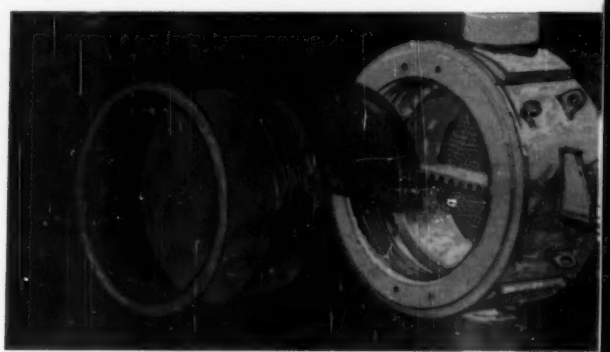


Condensate removal trays' unique location gives effective deaeration, higher vacuum.



Extremely low bundle entrance velocity, exceptionally large steam transportation lanes.





American-Standard feedwater heater has a closure designed for ease of assembly and disassembly—which won't leak, even against highest operating pressures. It's simple, with only four major parts: pass partition plate, closure, seal, weld or compression ring. Rugged...design stresses are much lower than required by ASME Code. Compact, with a diameter smaller than similar units.

As near as your phone . . . American-Standard Industrial Division Power-Lift Products and Services. Talk over your requirements with an American-Standard* Industrial Division product specialist. You'll find him well prepared and experienced—frequently able to base equipment recommendations upon precedents of proved success. And, in many instances, our comprehensive standardization paves the way to savings in time and cost. Offices in all principal cities. American-Standard Industrial Division, Detroit 32, Michigan. In Canada: American-Standard Products (Canada) Limited, Toronto, Ontario. Export Division, American-Standard, New York City.

AMERICAN-Standard
INDUSTRIAL DIVISION

AMERICAN BLOWER PRODUCTS • ROSS PRODUCTS • KEWANEE PRODUCTS

Surface condensers Designed to service the largest of today's and tomorrow's steam turbines. Low bundle entrance velocity; liberal steam transportation lanes; moisture impingement grids to extend tube life; expansion diaphragms; effective deaeration and many other features created during 40 years of surface condenser development and research.

Heat exchangers Designed and built with thoroughness and precision. Standard or specially engineered units for virtually all conditions and applications, including high pressure-high temperature exchangers, compressor inter- and after-coolers, fuel oil heaters, blow-down exchangers, and many others.

Mechanical draft fans Complete range of sizes and types for forced draft, induced draft, gas recirculating, and primary air fan applications. Designed to meet rigid requirements of modern power plants where maximum pounds of steam are produced daily at peak efficiency. Airfoil, forward curved, backwardly inclined, radial, radial tip blades.

Gyrol® fluid drive Provides stepless adjustable speed control for fans and boiler feed pumps. Performance, power savings, and reliability proved in the field. Units for motor driven boiler feed pumps or for "on-the-shaft" duty on main turbine generator. Drives are available for fan and pump duties for all boiler sizes.

Feedwater heaters Design incorporates unique new High Pressure Closure. Maintenance is simplified with only four major parts. Exceptionally high safety factor built into all units—more than double ASME Code requirements. Temperature stresses from start-ups or load changes virtually non-existent.

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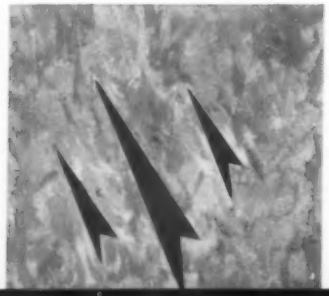

Power Engineering

ATOMICS

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BARRINGTON, ILLINOIS

A POWER ENGINEERING FEATURE FOR UTILITY & MAJOR INDUSTRIAL EXECUTIVES

A. W. Kramer, Editor

A Periodic Report on Atomic Energy Development Throughout the World Published by Technical Publishing Co.

January 1961

McKinney Reports Again. During 1955 and '56 Robert McKinney served as chairman of a panel on the "Impact of the Peaceful Uses of Atomic Energy" at the request of the Joint Committee on Atomic Energy of the Congress of the United States. His subsequent report of the panel's investigations was of significance, not only in that it represented an unusually comprehensive analysis of the factors involved in the development of atomic energy throughout the world, but also because it disclosed for the first time some of the work done in the United States in the field of controlled thermonuclear research. Even more important, the 1956 McKinney report urged maximum declassification of thermonuclear data and information in the public interest. Among other things the McKinney report was, no doubt, influential in the complete declassification of controlled thermonuclear information at the 1958 Atoms for Peace Conference in Geneva.

Last October Robert McKinney, again at the request of the Joint Committee, submitted another report on the state of atomic energy development throughout the world. This new report, the result of a year's investigation, entitled "Review of the International Policies and Programs of the United States", is even more astonishing in its scope and breadth of content than the 1956 report. It is published in five volumes totaling over 2000 pages. These volumes are available from the Government Printing Office at Washington at prices ranging from 35 cents for Volume 1, which constitutes the conclusions and recommendations of the panel, to $2.50 for Volume 4. The complete set of five volumes can be purchased for $6.85. At this price, this report provides more authentic information concerning the state of atomic energy development than could be obtained anywhere else. The immense amount of data covers every aspect of atomic energy development in virtually every country in the world, including the countries in the communist bloc. In addition, Section B of Volume 4, on Energy Resources, presents the most concise, yet extremely comprehensive, analysis of the world's conventional power resources to be had.

The new report is quite critical. According to the findings of the McKinney panel, the United States has not oriented its own peaceful domestic atomic activities to support the international political objectives to which it had assigned such great importance. The long-term financial commitments essential to most effective attack on complex technological problems were neither sought nor provided. Advanced reactor experiments and the imaginative -- though expensive -- research facilities and equipment needed for successful attack at the frontiers of atomic knowledge were too conservative, too few in numbers, and inadequate to the task. Instead, the report goes on, activities of the Atomic Energy Commission were primarily directed toward the development of hardware in support of demonstrations of current technology.

Changed Conditions. From the beginning the United States has looked at the peaceful uses of atomic energy from two standpoints: first, how we may use them at home for our own benefit and, second, how we may use them abroad for strengthening the Free World.

These should still be our objectives, but, as Mr. McKinney pointed out

in a statement to the Joint Committee in May, 1959, world conditions have changed considerably since the Atoms-for-Peace program was first proposed, and what seemed a wise course of action then, may now, under changed circumstances, prove unsuitable. It was against this background of changed conditions, particularly in Europe, that the second McKinney panel made its investigations.

Euratom. A key factor in atomic energy development in Europe is Euratom -- the European Atomic Energy Community. As originally conceived, Euratom had two objectives: the first was research and exchange of information in the atomic field. The second objective was the development of investments, common installations, supply of nuclear fuels, and other overhead services for atomic electric power plants. These were valid objectives.

Then came the Suez Incident. After it, as was proper, a study was made -- a sort of market analysis -- which resulted in a report, "Target for Euratom." This called for the creation of 15 million kilowatts of atomic-electric generating capacity in Europe by 1967. This target was arrived at in the clouded light of political, economic, and nuclear technological factors existing around the time of Suez. At that point it seemed that Western Europe might permanently remain the dollar-short, fuel-short, high-energy-cost area increasingly vulnerable to the interruption of fuel imports. Euratom then seemed to offer a mechanism, fortunately already in the process of creation, which would conserve foreign exchange and provide an alternate power source competitive with fossil fuels as to cost and less vulnerable to being cut off.

The conservation of exchange argument was weakened if not made obsolete by the action of Western European countries in January, 1959, on currency stability. What once seemed a permanent dollar shortage is now seen to be an ebbing tide. Also, the specific goal of kilowatts of atomic power, however great its merit appeared in 1956, seems much less urgent today, nor does it appear more urgent in the middle future.

In the long run, Western Europe will have a huge power demand, but just now it is not clear what energy will provide that power. In the meantime, it is good sense to carry on continuing research and development in the hope of realizing competitive atomic power. Practical men, however, must draw the line with regard to the word competitive. With freer Western European economy, with currency convertibility, and with the expanding export trade, atomic fuels will have to stand on their own feet in competition with coal and oil.

In 1955 and '56 a definite shortage of fossil fuels seemed imminent, and with the Suez crisis late in '56, the rapid development of atomic power seemed the only apparent solution. Today quite a different situation prevails. As a result of the many diverse and often conflicting situations produced by industrial technology, almost every shortage of the post-war period has now become a surplus. In the six nations that comprise Euratom, unsold coal stockpiles are excessive, and looming behind today's headlines of overproduction from existing oil fields is the unknown but huge potential of unexplored world-wide deposits.

What did Suez Prove? The conclusion seems inescapable that any shortage of fossil fuels has receded farther into the future. What the Suez crisis proved was the exact opposite of the public conception. Suez demonstrated a basic independence of Western Europe from oil deposits in the Middle East. Suez set the limits to what political regimes in oil producing countries can do. Realistically, they can neither cut off supplies nor raise prices. They are limited to trying to keep at home a greater percentage of a diminishing profit.

Over at least the next decade the trend in prospect for conventional fuel prices appears downward. All large energy-consuming centers in industrialized countries can be supplied with conventional fuels at not more than 30 to 40 cents per million Btu. In short, the conventional fuel industry has the ability to undercut efforts to make atomic power competitive and to do so almost instantly, without expensive research and development and without additional vast capital investments. The McKinney report states flatly that the era of fuel price disadvantage for other countries with respect to the United States has ended.

U.S. Atomic Policy. In view of these complex and rapidly changing factors, it is perhaps not surprising that the new McKinney report is critical of the U.S. effort in the nuclear field during the past three or four years. As the report points out, the United States has not planned its facilities or experiments or programed its research and development so as to take into full consideration the related activities of its close friends and allies among the atomically advanced nations. With the prospects for economically attractive atomic power diminished, some of these facilities -- the great scientific laboratories -- have now lost their sense of purpose and direction. Working alone they are unlikely to achieve low cost atomic power in any reasonable time. Indeed, working alone they have as great a potential for making world security problems more difficult as for making them simpler. Each country is now making in isolation its own choices for the future, including possible redirection to development of military uses, starting with naval ships and ending with nuclear weapons.

McKinney feels that the United States could have helped bring about a different set of circumstances by devising internal machinery of its own for laying out technical objectives on an international basis and by offering to program its own research and development efforts in the peaceful atomic field in concert with its friends and allies.

Euratom and the European Nuclear Energy Agency, although worthy organizations, are not in themselves capable of focusing the collective atomic laboratory capability of North America and Western Europe on peaceful atomic objectives valid in the light of today's changed circumstances. Because even in the United States there exists no machinery for laying out technical objectives on an international basis, the United States suffers a major handicap in any effort now to take the lead in devising North American-Western European working relationships.

The McKinney report claims that a broad obligation of the United States arose from its encouragement of the creation of the atomic laboratories of the Free World. Fulfillment of such a broad obligation is a more important attribute of leadership than the narrower legal obligations actually assumed and discharged. The United States has not drawn Free World atomic laboratories into concerted attack on mutually agreed objectives in order to make most effective use of the scientific and technological assets available. The physical and intellectual resources, however, have at least been brought into being. There are available American scientists and laboratory directors capable of providing the technical leadership necessary to make concerted attack most effective.

Effective atomic research programs in North America and Western Europe can be planned on a coöperative basis, while still insuring full national autonomy in decision making and while still providing for special local political considerations and commercial interests. This coöperation must not involve in any way the creation of new organizations in the course of carrying out their responsibility to make their own work most productive. Such a course, according to the McKinney report, requires only the injection into the present situation of the following new elements:

(1) Recognition by the U.S. Atomic Energy Commission and its laboratories of the importance of laying out its own broad technical objectives in full consideration of the combined capacities and competences of North American and Western European atomic laboratories.

(2) Mutual agreement at top policy and administrative levels in advanced industrial nations of North America and Western Europe as to over-all research and development objectives in the peaceful atomic field.

(3) Frequent, direct, and close working relationship between the countries concerned, both at the laboratory director and at the technical program director levels.

The new McKinney report makes clear that the United States has an obligation to support a far-reaching program of atomic energy development because of the humanitarian benefits to be derived from applications of atomic energy in

the field of medicine and biology, agriculture, food preservation, industrial production, water purification, and many other areas, including direct conversion of energy into electricity.

Dr. Jekyll and Mr. Hyde. Atomic energy has, on the one hand, complicated the problems of individual and public health and has, on the other hand, advanced man's knowledge of and ability to deal with these problems. Radiation changes all substances to some degree; for man these changes can be fatal. As use of atomic energy becomes more widespread, increased discharge of radioactive materials into the air, ground, and water augments the industrial-age problems of contamination of these main elements of man's environment. Yet atomic energy also provides new means of studying — even of changing — life processes and the surrounding biosphere. It gives us new means of diagnosing and treating human ills.

For less developed countries atomic radiation and isotopes provide new tools with which to attack infectious diseases and malnutrition. These tools require a sound medical base, oriented first to public health and next to individual health. To further these ends the research needed must be conducted in medical research centers in the countries where the problems are found. In less-developed countries, these centers are too often lacking or inadequate. Misdirection of the needed effort in this area can result in diversion of limited scientific strength to premature activities such as basic research or atomic electric power — premature, that is, in relation to immediate health and food problems.

Thus, it is towards a more intimate and active coördination of United States effort with that of other countries that the McKinney report addresses itself. The image of the United States as it appears to other nations is created not only by the gross economic and political actions which express national policy but also by the character of the principles and projects supported. With respect to atomic power, the McKinney panel points out, there has been little concern in either the AEC or the State Department that inability to reduce atomic power costs more rapidly could adversely affect achievement of the original disarmament objective established in 1954. In its role as the principal source of advanced atomic technological assistance to the Free World, the United States considered other industrially advanced nations as potential recipients of U.S. atomic assistance rather than as potential partners. There was no concerted international research and development effort directed to the achievement of atomic power which could still be economically attractive in the light of changing circumstances and hence could result in widespread application more quickly.

Andrew C. Kramer

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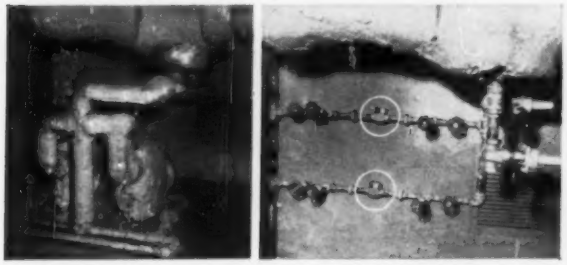
SARCO TOPICS

How major New York office building solved steam trapping problems through trap standardization

Recently, the Office Building at 625 Madison Avenue, New York, — erected in 1931 and comprising 420,000 square feet on 17 floors — discontinued its own steam generation and switched to district steam. The changeover made the inadequacies of old bucket and float traps more apparent than ever, and afforded an occasion to modernize trapping. Here's how major improvements were made.

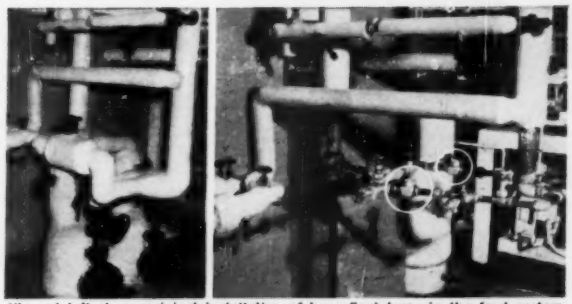
The first problem was maintenance. All maintenance had to be done at night or on weekends, at overtime rates, because the system could not be shut down during business hours. Frequent breakdowns added to maintenance costs. After the installation of Sarco Thermo-Dynamic Steam Traps, Type TD-50, trap maintenance — and therefore maintenance costs — have been reduced almost to zero. The engine room crew are now free for other jobs, and savings in both regular and overtime manhours are considerable.



Left picture shows the steam service main from the street, with massive float trap installation. Picture at the right is view of installation after the changeover to TD-50's (circled).

The second problem was water-hammer, caused by passage of live steam into return lines when traps failed open. (When traps failed closed, water accumulated in steam supply mains and equipment.) Installation of TD-50 steam traps ended waterhammer and consequent damage to equipment, because the TD-50 discharges condensate as rapidly as it is formed and prevents steam from entering the return system.

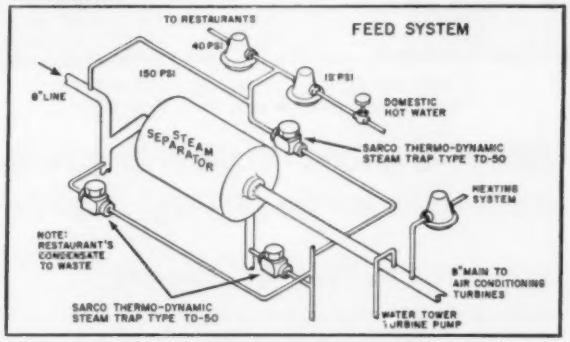
The third problem was live steam loss. Live steam, discharged into the return lines, not only represented a great waste of heat energy, but caused waterhammer in the return, and raised the condensate temperature to an excessive level. (Incidentally, although the building's district steam system is, of course, not faced with this problem, hot condensate passing through condensate pumps can damage pump seals.) These problems are eliminated through the use of TD-50's. No steam can be blown into the return main because the TD-50 shuts off *positively,* blocking any possibility of live steam being discharged into the return. Savings are considerable.



View at left shows original installation of huge float traps in the feed system of the building. View at the right shows compact installation of Sarco TD-50 Steam Traps (circled).

These benefits were achieved by replacing bucket and float traps with Sarco Thermo-Dynamic Steam Traps, Type TD-50, matched and correctly sized to the application. For example, many ½" bucket traps were replaced with ⅜" TD-50's, which have ample capacity for the job.

The TD-50's pressure range of 10-600 psi made it possible to standardize on one steam trap for a variety of applications that formerly required traps of many different types and pressure ratings. Finally, changeover took only 30 minutes per trap for each compact TD-50 installation.



Schematic hook-up of the converted feed system.

The success of this TD-50 installation led Collins, Tuttle Co., Inc., managers of the building, to substitute Sarco Thermo-Dynamic Steam Traps for competitive bucket traps in two other major New York buildings.

For more information on Sarco Thermo-Dynamic Steam Traps, contact your Sarco Sales Representative or district office, or write.

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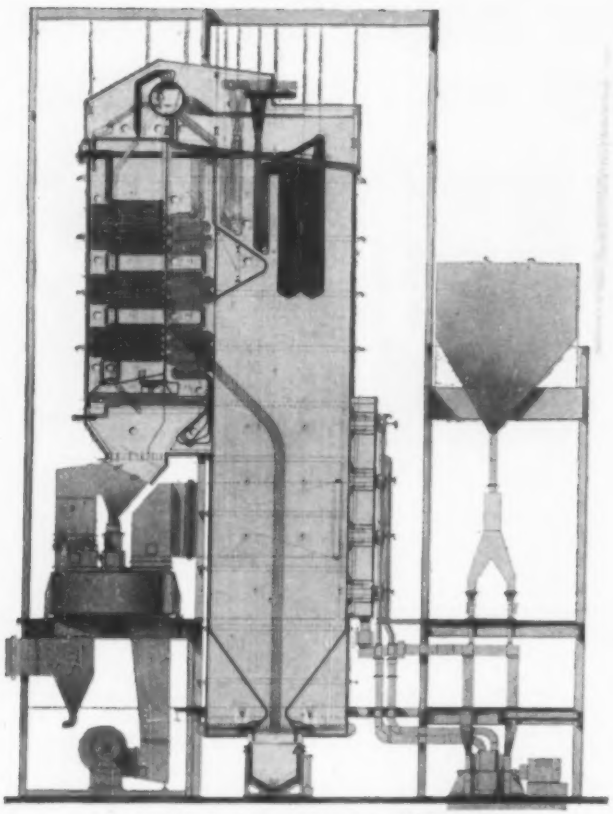

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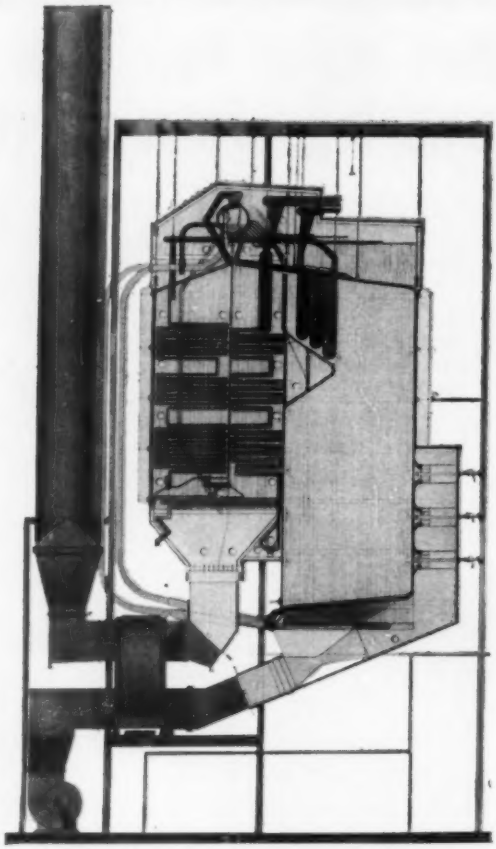

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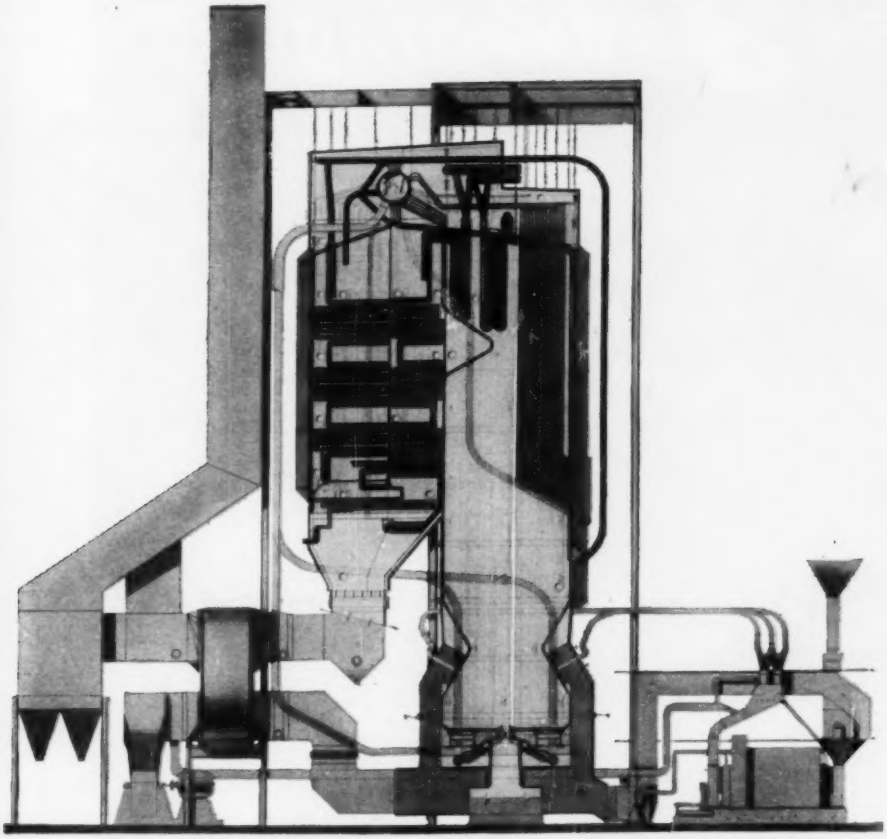

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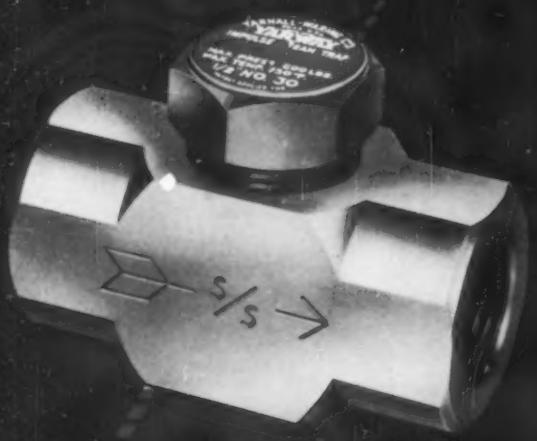

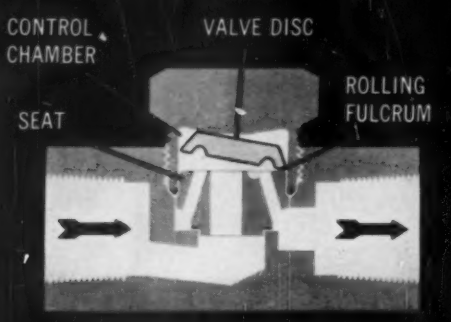

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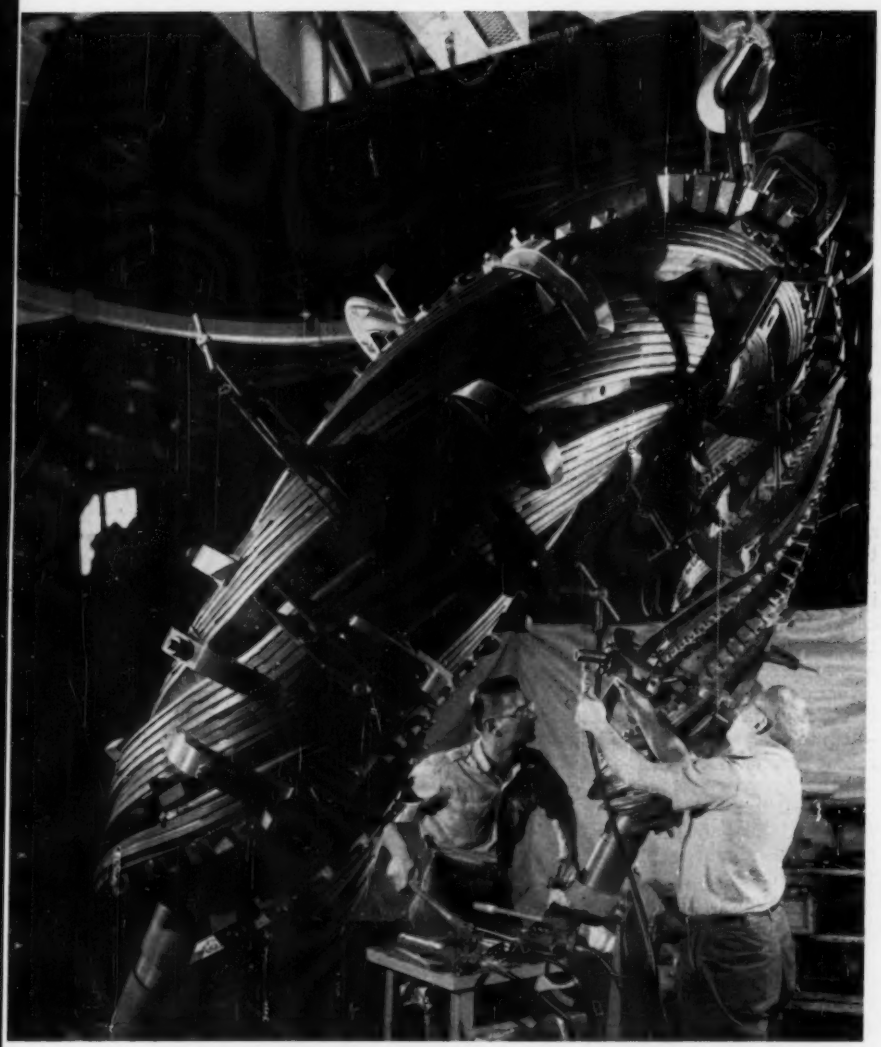
EXOTIC POWER



Stabilizing field winding of a coil for the C-Stellerator—the research device designed to produce thermonuclear power. One of a pair being built. The twisted helical winding will carry in excess of 44,000 amp of pulsed d-c at 750 v. The winding twists the magnetic field to increase the effectiveness of the magnetic bottle and thus permits a higher temperature in reaction chamber. Following pages show other developments

Exotic Power is a term that has come into use to denote various new concepts for the direct conversion of energy into electricity. Not since atomic energy was new has there been so much excitement about a new technology as there is in this area of exotic power. It involves not only the re-investigation of old principles such as thermoelectric and thermionic action, solar energy, and fuel cells, but also work that is being done in the thermonuclear field. Only a few exotic power units have yet emerged from the laboratories and these are very small devices, developed largely for use in space vehicles. The present research lies at the basic levels of physics. Often it involves elaborate and expensive equipment. The strange mass of equipment in the photograph on this page may not look like a piece of laboratory apparatus, but it is a vital part of the $35 million C-Stellarator being fabricated in the shops of Allis-Chalmers for installation at Princeton in the Matterhorn project. Some day devices of this character may generate exotic power on a stupendous scale. Although much has been written on the various new power concepts in recent years, progress is so rapid that frequent reappraisal of the state of development in the respective areas of research is desirable. With this thought in mind we are pleased, in this special section of POWER ENGINEERING, to present a general review of the work that is being done on the development of these new concepts at the frontiers of power research.

Andrew C. Kramer
EDITOR

FRONTIERS IN POWER RESEARCH

By Andrew W. Kramer
Editor ATOMICS

In the relentless search for new energy sources and new methods of generating electricity, engineers and scientists are exploring every known principle of physics and chemistry and are re-examining previously tried concepts in the light of modern technology. Nuclear energy, both fission and fusion, solar radiation, thermoelectric and thermionic principles, as well as fuel cells and ion acceleration, are all under intense scrutiny here and abroad

HUMAN PROGRESS through the ages can be measured by man's ability to turn the energy with which Nature has supplied him into the various forms which accomplish the purposes most desired at the time. Until the development of nuclear energy all power had its origin in the sun. The heat developed in our pulverized coal- and oil-fired boilers is as much power derived from the sun as is the energy which actuates a photoelectric exposure meter in the summer sunshine. The latter represents a direct use of the sun's power, but most of our use of solar energy is indirect. Of the indirect solar energies there are two kinds: the physical, such as the power of the winds, waterfalls, solar tides and waves, and the chemical energies in the oxidation of carbon and hydrogen stored by the sun's energy in organic materials.

Of the chemical energies, those resulting from internal oxidation refer to foods, and those resulting from external oxidation refer to fuels. Of the fuels there are natural gas, liquid petroleum, vegetable oils and alcohols. And in the solid fuels we have coal, old and limited in amount, and wood, modern and continuous in supply. Such, briefly, is an inventory of the energies available to man before January 1939, when the news of the discovery of nuclear fission swept through the scientific world.

The announcement of nuclear fission marked a profound change in the world's energy resources. For the first time in his existence man was possessed of a source of energy which did not stem from the sun and which had a vastly greater potential than all the fossil fuel reserves laid down by the sun through the ages. According to recent surveys, it is estimated that the heat energy in the uranium reserves of the world is about 25 times as large as the heat in the world's coal reserves.[1] This estimate is based on the coal available at present prices and, in the case of nuclear fuel, assumes a regeneration ratio of 1.4.*

Although the conventional fuel resources of the world are adequate to fulfill the world's power requirements for many future decades, there is no reason to assume that they are as inexhaustible as they were once thought to be. Although there are no agreed methods for forecasting energy demands, especially demands for electricity, for the intermediate term — up to the year 2000, projections of recent trends have some validity.

Year by year increases in energy demand will certainly continue. Rising standards of living will involve acquisition by more people of present types of energy-consuming devices, such as automobiles and appliances. Increases in demand will also arise from introduction of new types of appliances.

Demand vs Supply

There is thus good reason to believe that the continually increasing demand for energy will bring about a depletion of at least the more easily recoverable fossil fuel reserves in the not too far distant future. Whether the pinch will come in the next 50 or 100 years is not of significant importance; the fact remains that the fossil fuel reserves of the world are limited in amount, and it is this knowledge that has caused a number of people throughout the world to become concerned about future energy sources.

Although the estimates of the world's fossil fuel reserves are considerably brighter on the basis of the most recent estimates than they were ten years ago, especially with regard to Western Europe, there are many reasons for investigating other sources of energy.[2] Twentieth century society is increasingly interdependent, but traditional political concepts of sovereignty and self-sufficiency still prevail. Nations are hesitant to rely on vital energy resources not under their direct control, yet the distribution by nature of conventional energy resources is so mismatched with the centers of industrial populations that almost all industrialized nations now require energy imports.

For different nations, atomic power has appeared to offer some opportunity to minimize imports, or at least to increase the diversification of supply sources from which vital energy requirements can be drawn. This is the *classic* strategic argument which can motivate nations and regions to accept higher costs in return for greater independence from factors beyond their control. Economically attractive atomic power arising within each country could ultimately provide new and severe competition for high-cost domestic fuels which have in the past been able to rely on protective tariffs and other political devices for competitiveness with low-cost fuels from other parts of the world. The advent of cheap nuclear power might be the means for continuing and extending the historic Western industrial leadership, based on low-cost energy.

In the long term — beyond the year 2000 — vast populations and

* Regeneration ratio is defined as the gross number of fissionable nuclei produced per fission, including fissions of U^{235}, U^{233}, Pu^{239}, and Pu^{241}.

worldwide industrialization presage vast energy demands which must inevitably tax the finite limits of conventional energy resources. Science and technology must be put to work in such areas as controlled thermonuclear power, even though promising avenues toward commercialization are not yet evident. In the meantime, conscious conservation must take the place of unconscious waste. Both fossil and atomic fuels must be used efficiently to give the time needed for the achievement of longer term solutions.

Because of these many complex factors, serious attention is being given in many quarters to the investigation of new sources of energy and new methods of power generation, as well as to re-examination of previously tried concepts that were discarded because they did not appear technically or economically feasible at the time they were discovered. In a world which is changing as rapidly in all its various aspects as ours is, it is unwise to assume that our present methods of generating electricity will survive any more than did the steam engine, once our prime source of mechanical and electrical power. It is possible that the next 50 years will bring about radical changes in the various forms of power available to us and that the power plant of the 21st century will house strange new machinery of such power that even the 500,000-kw turbogenerators now contemplated will seem small by comparison.

It is quite reasonable to believe that the coal- and oil-fired boilers of today will not survive the change any more than did the steam engine of earlier years. It is only necessary to compare the noise of the conventional boiler with the silence of the nuclear reactor to understand the nature of the changes that are under way. The silence of the reactor alone is sufficient to remind us that mechanical energy in the old sense is fast disappearing from some aspects of power production.[3]

Nuclear power, however, is only one element in the new though admittedly cloudy-crystal ball picture of power development. Of great significance in future power development is our deeper insight into the realm of solid state physics. Seldom has any group of materials so quickly vaulted into a position of prominence, or so greatly aroused the imagination of the technical public as have the semiconductors, as exemplified by the transistor. In the semiconductor lies the future of thermoelectric energy conversion. The thermoelectric or Seebeck effect was discovered in 1822, but except for its use in the measurement of temperature, it remained of little practical importance until it was re-examined in the light of semiconductor theory. Now, with greater knowledge of electric conduction in solids, the Seebeck effect signifies promise of a new, highly efficient thermoelectric generator.

New Searches, New Sources

Aside from problems of impending scarcity of fuel resources, there are other reasons why it is desirable to investigate new power sources. One of these reasons lies in the increase in the carbon dioxide content of the atmosphere as a consequence of the burning of fossil fuels. In the opinion of some scientists, this is a more disturbing factor than the problems involved in the disposal of radioactive wastes from nuclear power plants.[4]

Another motivating factor in the search for new methods of power generation is the inherent thermodynamic inefficiency of the steam cycle used in all the steam-electric generating plants at present. Further improvement in the efficiency of the steam cycle is rapidly approaching the limit of diminishing return. Theoretically it is possible to improve the steam-cycle efficiency by extending the high temperature range, but here we are limited by the characteristics of materials at high temperature. At present this limit appears to be around 1050 or 1100 F.

These facts concerning present methods of generating power, coupled to a growing awareness that there may be simpler ways of producing electricity than through the steam cycle, make it desirable to examine the entire field of energy conversion more critically than ever before. In addition to the work being done on the direct conversion of thermal energy into electricity by means of thermoelectric and thermionic action, the development of devices for the direct conversion of chemical energy into electricity also is the subject of intensive investigation in the United States and abroad. Most of this effort is being directed toward the development of a practical fuel cell in which fuels are converted directly into electricity by oxidation.

The fuel cell may be thought of as a continuous primary battery. In the original concept of the fuel cell the fuel was to be coal and the oxidant air, but this has been broadened to the point where any anodant reactant in a battery may be considered as a fuel provided that it can continuously be fed into the cell. Recent developments in fuel-cell technology are discussed on pages 67 to 71 of this section. Direct conversion of thermal energy into electricity by thermoelectric and thermionic methods and the use of the magnetohydrodynamic principle form the subject of the special article on direct conversion by H. M. Ogle beginning on page 57. New aspects concerning the use of nuclear energy and solar energy are considered in the pages immediately following.

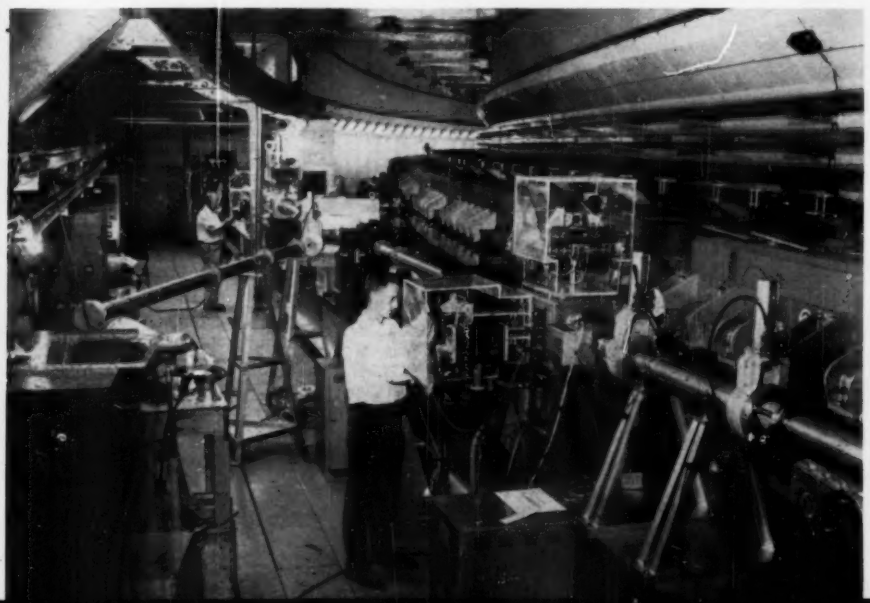


Fig. 1. This extremely complex mass of equipment may seem far removed from the field of power generation, but the knowledge of nuclear structure which it may bring to light may some day bring us a source of energy sufficient to maintain our industrial civilization going for a billion years. This view inside the tunnel of the new 25-Bev Brookhaven Alternating Gradient Synchrotron shows the 50-Mev proton accelerator in the foreground. The 50-Mev proton beam leaves the Linac, located behind the shielding wall, and travels along the 4-in. pipe into the orbit of the synchrotron magnet ring

Fig. 2. SNAP 10, shown being assembled here, is probably the simplest nuclear power plant ever built. It will generate auxiliary electric power for space vehicles directly without moving parts. Operation of the core was announced by Atomics International last August

NUCLEAR ENERGY

THE MOST CONCENTRATED, THE CLEANEST, AND THE MOST EASILY CONTROLLED SOURCE OF ENERGY MAN HAS EVER HAD. ITS MANY FACETS ARE BEING EXPLORED IN LABORATORIES ALL OVER THE WORLD

NO ENGINEER who has ever visited the Shippingport Nuclear station and looked down into the clear distilled pool of water that covers the reactor pressure-vessel head while the reactor is in operation can fail to have been impressed by the silence that prevails. Underneath the undisturbed surface of the water is a pressure vessel containing a core six feet high and slightly over six feet in diameter, which produces some 230,000 kilowatts of thermal energy.

The fuel temperature averages around 1000 F. There is no noise, no vibration, no smoke, dust, or fumes of any kind, yet this seemingly inert device is capable of producing this vast amount of energy, day after day, month after month, without replenishment and without an inordinate amount of attention. If the electrical load on the generator undergoes sudden fluctuations, the inherent negative temperature coefficient of the pressurized-water moderator automatically adjusts the thermal output of the reactor to that of the electric generator.

This is nuclear energy, the most concentrated, the cleanest, and perhaps the most easily controlled energy source man has ever had at his disposal. When one considers the fact that the energy in one quarter of a cubic inch of uranium-235 is equivalent to the energy stored in 5000 cubic feet of coal, the tremendous impact of nuclear energy upon the world becomes apparent.

Power From Nuclear Fission

In the area of fission, techniques are well established and a number of different reactor types have been developed. Those which have proved most successful to date are the gas-cooled graphite moderated units developed in England, and the pressurized-water and boiling-water reactors developed in the United States and Russia. All of these types use solid fuel elements containing either natural or enriched uranium.

There is no reason to believe, however, that these gas- or water-cooled reactors as they are designed today will not be superseded by greatly improved types in the years to come. A number of advanced reactor concepts are presently under consideration, and construction on some of them has been started. By the use of various combinations of fuel, moderator, coolant, fertile material, etc, a large number of different reactor concepts are possible, but it is unlikely that many of these theoretically possible types will prove practical. In surveying advanced reactor concepts it is helpful to consider nuclear systems with respect to the fission energy they provide. This makes it easier to perceive the ultimate goal of nuclear energy somewhat more clearly.

For example, the most important characteristic of nuclear fuel is its low cost as mined. This provides the impetus for the current development of central station power and low quality process heat.[4] The latter is mentioned because the intrinsic low cost of nuclear fuel as mined represents the primary advantage of nuclear reactors in this application. Power reactor technology ought to be bent toward using the nuclear fuel in the most economical fuel cycle. Capital cost of reactors can be reduced, but there is no particular virtue to nuclear power unless the intrinsic low cost of the fuel is preserved.

Another characteristic of nuclear fuel is its compactness, already men-

tioned. One gram of U^{235} is capable of producing about 24,000 kwh of heat. When this capability is coupled with the intrinsically compact structure of nuclear reactors, all sorts of applications where fuel or system size and weight are restricted may be suggested.

Of particular interest in this area are the three nuclear space electric power units under development by the AEC for the U. S. Air Force and the National Aeronautics and Space Administration. The electric output of these three systems extends over the power range of 300 watts to 35 kw. The three systems include the SNAP 10 power unit, which is a demonstration system utilizing thermoelectric power conversion. The system covers the sub-kilowatt region of power and has no moving parts. The extreme simplicity provides assurance of obtaining remote orbital start-up, high reliability, and long endurance.

SNAP 2, which utilizes a similar compact nuclear reactor, weighing about 200 lb and which is cooled with liquid NAK alloy, is coupled to a small mercury vapor turbine-alternator power conversion system. This system has a 3000-watt output with one turbine, but future extension would permit the use of two power conversion systems with one reactor for a total power of 6000 watts. The third system, SNAP 8, is a direct outgrowth of SNAP 2 power plant and will deliver 35 kw with one mercury vapor turbine. It will deliver 70 kw with two power conversion systems coupled with the same reactor. At Atomics International, a SNAP 2 reactor has operated continuously for 1000 hours at a coolant outlet temperature of 1200 F.

SNAP 10 has a total weight of 355 lb; SNAP 2, with its 3000-watt output, weighs 600 lb, and SNAP 8, with its 35-kw output, weighs 1200 lb. Thus, these three systems are rated at 0.9 watts, 5 watts, and 29.2 watts per pound, respectively.

Another characteristic of nuclear fuel that is important is that it does not need any other material for its burning. This adapts nuclear power to such airless environments as the bottom of the ocean and space. The same feature makes nuclear heat chemically passive and suggests the possibility of its use for chemical and metallurgical processes where high temperatures are desired.

Containment Aspect

An aspect of nuclear fuel that thus far has been considered a drawback is the need to contain fission product wastes for long periods of time. However, the very fact that such wastes have to be strictly confined may prove to be a basic advantage, since, unlike the CO_2 and noxious gases from fuel-fired plants which are dispersed to the atmosphere, nuclear wastes, properly confined, will not contaminate the atmosphere.

A feature of nuclear energy that has not been explored very much is its ability to deliver sharp and controllable pulses of energy. The Plowshare (underground nuclear explosions) experiments have already illustrated some applications of the largest and most violent pulses. However, except as sources of neutrons for research purposes, little consideration has been given to technical applications of pulsed systems. Pulsed reactors such as Argonne's TREAT reactor repetitively deliver pulses of 10,000 megawatt-seconds within a tenth of a second. The Los Alamos Godiva system can shorten the time scale of the pulses by another factor of 100. It is, in principle, possible to convert this energy directly into mechanical shocks. These are traveling pulses of very high temperature and pressure.

Perhaps the most unique feature of nuclear energy is the fact that virtually all of the energy of the fission process goes into ionizing materials in the reactor, and heat appears only when these ions are recombined. Thus, by virtue of these radiations, energy may be stored in various ways. It has been suggested that fission products stored in a block of glass could be used to heat water or air to moderate temperatures for space heating.

Aside from the possible uses of the radiations from reactors, the reactor itself is an important research tool. The history of reactor development indicates that an overwhelming number of technological advances in other applications are pioneered by applications in research reactors; for example, the concept of the *Nautilus* developed out of the materials testing reactor (MTR). And in the area of transmutation, a reactor's oldest use, the possibilities for the exploration of elements beyond plutonium in the periodic table are enormous. Among the transuranic elements of greatest purity, for example, is Californium, element 98, with its mass 252 isotope. This isotope undergoes spontaneous fission with a half-life of two years, and if any quantity could be made, it would represent by far the most concentrated power source available.

Nuclear power needs more intense exploration, not only for large base-load, central station plants, but also for remote, including space and undersea, seasonal, peak load, and emergency, uses.

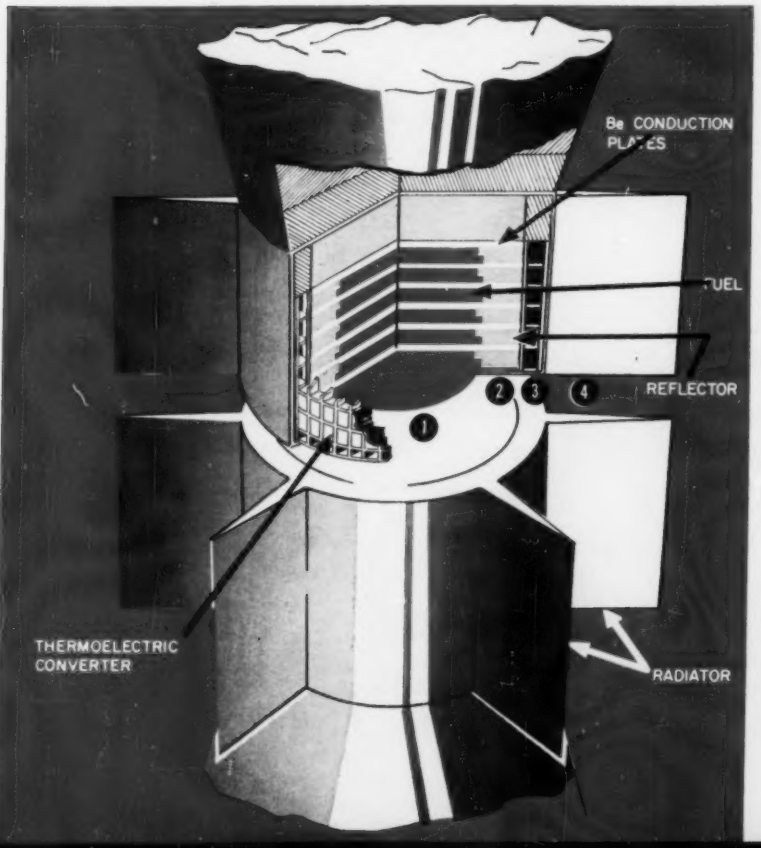


Fig. 3. The simplicity of SNAP 10 is shown by this diagram. It consists of a core of uranium-zirconium hydride fuel plates surrounded by a beryllium reflector. Heat from core is conducted through the reflector directly to the thermoelectric converter

FUSION—THERMONUCLEAR REACTIONS

THE SECOND basic principle by which nuclear energy is released is by the fusion of light elements into heavier elements. This principle is demonstrated most dramatically in the explosion of the thermonuclear or hydrogen bomb, and, of course, it is also the principle by which the energy in the sun and stars is released. In the sun, hydrogen nuclei combine to form helium nuclei, and in this process of *fusion* an enormous amount of energy is released.

It is toward the controlled release of this energy of fusion that Project Sherwood is directed. It is hoped that by raising a plasma to a sufficiently high temperature (measured in terms of tens of millions of degrees) fusion of the atomic nuclei will take place with the release of large amounts of energy. Not the least important aspect of this type of energy release is the possibility of removing the energy directly as electrical energy. A vast amount of research in this area of nuclear fusion is in progress throughout the world. In this country, this research is being carried out by the Atomic Energy Commission under Project Sherwood. Various approaches are being investigated. Since the temperatures necessary in a controlled thermonuclear reaction range from 40 to 100 million degrees and since no material bodies could contain such temperatures, all experiments involve the containment of the hot plasma in a magnetic field — the so-called *magnetic bottle* of the popular press.

The whole idea of magnetic confinement is that the hot (and therefore charged) particles of the plasma tend to follow along the magnetic field lines, provided that this field does not change too rapidly in space and time. The Stellarator concept of Spitzer[5-6] is based on this principle and, as it is being carried out under Project Matterhorn at Princeton, N.J., involves the largest and most elaborate experiment in controlled nuclear fusion in the United States.

It is not feasible here to describe in detail all the various experimental approaches being used in the effort to achieve a successful controlled thermonuclear reaction. One can think of many hybrid methods, but four schemes show promise. These four approaches are illustrated in Fig. 4. In the Pinch method used at Los Alamos, Berkeley, and Livermore, tremendous currents are passed through the ionized gas or plasma. The magnetic force of the current tends to constrict or *pinch* the plasma toward the center line of the doughnut-shaped (torus) tube. Thus, the plasma pinches itself with great increase in density and temperature.

Straight tubes are often used in studying the phenomena, but the

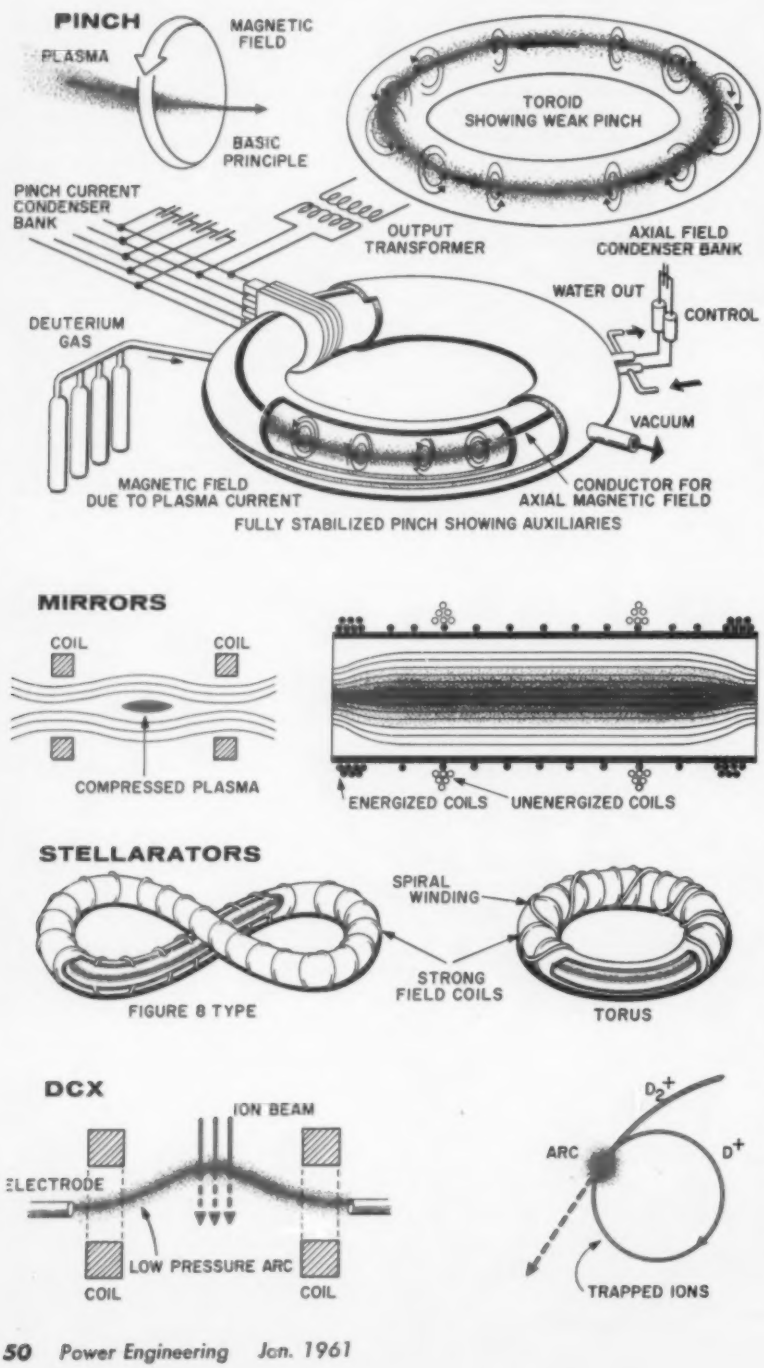


Fig. 4. Four promising schemes for achieving a controlled thermonuclear reaction. The Pinch is under investigation at Los Alamos, Berkeley, and Livermore. Mirror machines are used in various laboratories in different ways. The Stellarator concept is being developed at Princeton under the direction of Dr. Spitzer. DCX is the province of the Oak Ridge National Laboratory. It involves the dissociation of energetic ions by an electric arc

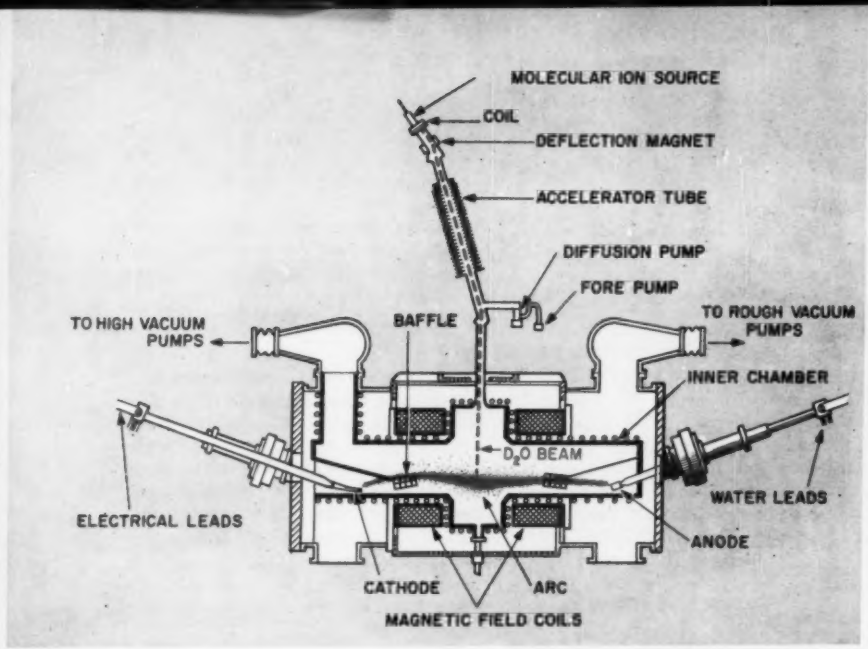


Fig. 5. Here is a simplified diagram of the latest version of ORNL's machine. The usual current in the arc is from 200 to 300 amp at 150 volts. It is approximately five feet long

main effort involves the use of the doughnut-shaped tube shown in the illustration. The idea sounds simple but it isn't. The thin filament of high density plasma tends to be unstable, and many refinements are necessary to provide stability and long confinement.

At the Lawrence Radiation Laboratory of the University of California, Dr. R. F. Post has built his magnetic mirror machine. In this experiment energetic ions (with accompanying electrons) are injected into a strong field provided by two large coils. At first the ions run in spirals nearly at right angles to the field. Then the current in the big coils is increased. This squeezes the hot gas. In different designs it is possible to squeeze the gas radially and to push it together along the axis. It is also possible to push the gas from one chamber to another.

In the Princeton Stellarator, they start with a cold gas, confined by a very strong magnetic field. A small current is passed, and then a larger one is caused to flow by transformer action. This brings the gas to something more than a million degrees. At that point this heating method is no longer satisfactory because the electrical resistance of the gas becomes too low.* Therefore the next step is to shake the gas with very strong alternating magnetic fields. This heating process is called magnetic pumping. Under these conditions the gas tends to drift towards the walls, but Dr. Spitzer first overcame this to a large extent by bending the doughnut into a shape like a pretzel. Later, it was found that good gas confinement could be achieved in a doughnut by ingenious tailoring of the magnetic field. Both methods have been under study at Princeton.

* A well-ionized gas may have an electrical resistance far less than that of a solid copper bar occupying the same space.

Work at Oak Ridge

The work at Oak Ridge National Laboratory, illustrated in Fig. 4 (DCX), is devoted to filling a confinement-space with super-hot ions; that is, ions that have an energy far superior to the ignition energy. It rests on the idea that an extremely hot plasma of low density has good confinement properties and can be used to heat cooler ions which are added after the very hot gas plasma is formed. Loss of hot ions by trading of charges with the residual gas molecules in the vessel is the chief enemy in this method; it is, however, minimized when the ion energy is very high.

With this method molecular ions can be trapped inside the confinement space. Molecular ions are introduced and are dissociated. Each molecular ion breaks up into an atomic ion (a deuteron) and an atom of deuterium. The atoms escape, but the hot ions are caught on smaller orbits and circulate in the confining magnetic field. The process depends entirely upon efficient dissociation of the molecular ions. It is not enough to let them encounter molecules in the residual gas.

An essential step in the process was attained at Oak Ridge when they developed a high-vacuum, high-current arc in which the high-energy molecular ions can be broken up with considerable efficiency. Work on this method, so far, has been done with continuous injection into mirror coils with direct current. Hence, the apparatus is called the DC Experiment or DCX. In Russia, work has been in progress along similar lines with a machine called the OGRA.

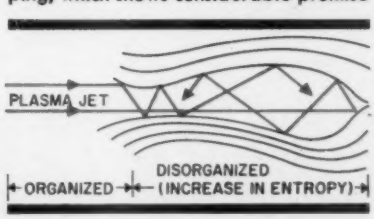
Entropy Trapping

A most recent development in the field of thermonuclear research is the principle known as entropy trapping,[7] developed at Los Alamos under the direction of James Tuck. This is a principle which gives promise of great hydromagnetic stability. It involves what is known throughout the world as cusped geometry, but at Oak Ridge they call it the picket fence. It is a magnetic field with magnetic lines curved away from the plasma. When this idea was thought up several years ago, it was not considered as being of particular importance — it was a very leaky way of doing things. As time went on, however, the idea began to look better, but there never was a decent way of putting any plasma inside of the cusped magnetic field. This is where the idea of entropy trapping seems to be paying off.

The idea is to take an intense jet of plasma from a previously developed plasma gun and project this at the axial cusp of a picket fence. The jet is intended to drill through the magnetic field and fill the interior of the hollow picket fence. It is predicted that the process of drilling through the magnetic field will cause the jet to become diffused or disordered (an increase in entropy) so that it loses its penetrating power and is unable to drill its way out on the far side.

This experiment now has top priority at Los Alamos and while proving somewhat more complicated than was envisioned in the beginning, it is looking rather hopeful. According to Dr. Tuck, it is certainly possible to keep the plasma inside the picket fence long after the gun has been turned off. The main surprise that has come out of the experiment so far has been that the opening and closing of

Fig. 6. The principle of entropy trapping, which shows considerable promise



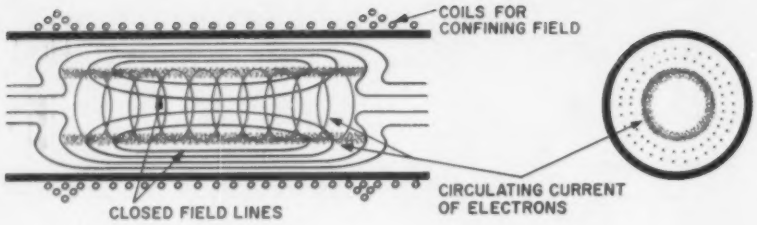


Fig. 7. The Astron concept utilizes a circulating layer of electrons held in place by an axial magnetic field. When the current in this layer reaches a certain value, the shape of the magnetic field changes to form a pattern of closed magnetic lines of force, as shown

the magnetic field turns out to be more gradual than expected. If the entropy trapping into the picket fence works out and fulfills the expectations of Dr. Tuck and his associates, they will be ready with a geometry by which the cusps are closed on themselves and the whole system wrapped up in a torus. This geometry, the caulked picket fence, is not new, having been proposed by C. L. Longmire and Tuck in 1957, but what is new is a levitated method of construction which may have the effect of stopping up the last few holes in it.

The levitated caulked picket fence is a complicated device and the group at Los Alamos have no intention of building one until they have obtained more results from the simple picket fence studies now in progress. With the simple equipment, they have actually achieved high density plasma for 30 microseconds, which is much longer than anything like this has ever been held before. In commenting on this work Dr. Tuck admitted that he had never been much of an optimist regarding thermonuclear reactions but that in this device, for the first time in all of the Sherwood work, he sees faint glimmerings of a possibility of making a thermonuclear reactor.

The above brief and exceedingly sketchy account of some of the work that is being carried out can only reflect dimly the intense interest in this field of research throughout the world. Virtually the same ideas that are being tried out here in the United States are also being tried out in Great Britain and in Russia. The Russian nuclear scientists who recently visited Los Alamos were intensely interested in the entropy trapping scheme and said they would try it out on their OGRA, which is a very nice machine to try it on.

Primary Objective

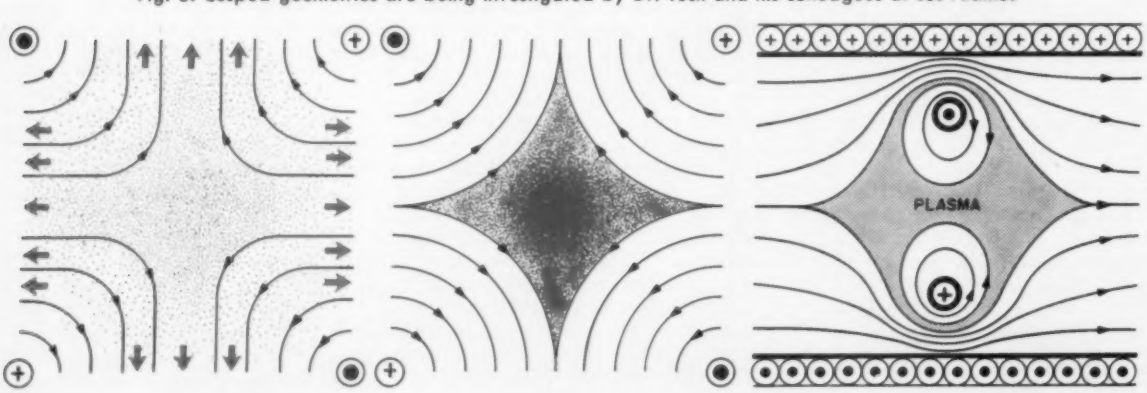
The primary objective in controlled thermonuclear research is to achieve very high temperatures at very high density. At Oak Ridge in the DCX work, the ions are put in at superthermonuclear temperatures. This means billions of degrees, while the ignition temperature of a deuterium-tritium mixture is only 50 million degrees. Oak Ridge, therefore, has the necessary temperature but the plasma is much too thin. There, it is necessary to improve the density of the plasma. At Los Alamos and the Naval Research Laboratory, on the other hand, they have shock mirror machines which are now operating at particle energies of the order of 15 to 20 million degrees centigrade or 27 to 36 million degrees Fahrenheit. This means that the present temperatures will have to be increased by a factor of three or four in order to reach the 50 million centigrade or 90 million degrees Fahrenheit level.

According to Dr. Arthur E. Ruark,[4] Chief of the Controlled Thermonuclear Branch, U. S. Atomic Energy Commission, in the last three years the energy of the dense plasma and the middle-density plasmas in the laboratories has been increased about tenfold. It is necessary to increase these densities by a factor of three or four in order to reach the ideal temperature of 50 million centigrade. This, Dr. Ruark says, is not a particularly significant point, except that when it is reached, the scientists will know that they are really on the way to still better results.

The stakes in the achievement of a controlled thermonuclear reaction that can be used as a source of power are very high. Once achieved, it could free mankind virtually forever from developing other sources of power. The amount of deuterium in the oceans is sufficient to supply the world's power needs for a billion years. Aside from the magnitude of the stakes involved, the achievement of a controlled thermonuclear reaction involves a great intellectual challenge. The work is just plain tough, and scientists like to bite into problems which strain their capabilities.

Dr. Raurk believes that thermonuclear temperatures will be attained in a relatively short term of years. This belief, he points out, should not be confused with the general verdict of thermonuclear physicists that 10 to 20 years might be required for the development of the first fusion power plant. Indeed, no one can yet say with certainty that this second step will be feasible.

Fig. 8. Cusped geometries are being investigated by Dr. Tuck and his colleagues at Los Alamos



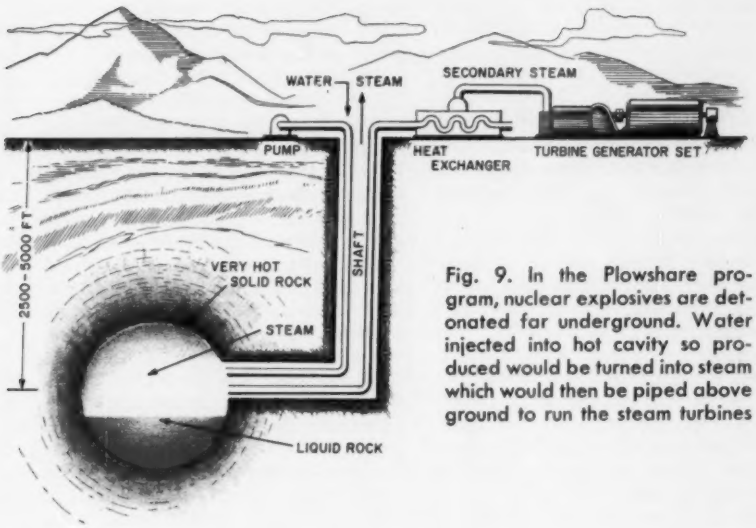


Fig. 9. In the Plowshare program, nuclear explosives are detonated far underground. Water injected into hot cavity so produced would be turned into steam which would then be piped above ground to run the steam turbines

PEACEFUL USES OF UNCONTROLLED THERMONUCLEAR ENERGY

THERE ARE MANY WAYS WHEREBY MANKIND COULD BENEFIT FROM THE EXPLOSIVE ENERGY OF THE HYDROGEN BOMB. FIRST, HOWEVER, SOME OF THE FEAR AND CONFUSION ABOUT NUCLEAR ENERGY MUST BE DISPELLED

BECAUSE OF the all but insuperable difficulties inherent in the effort to achieve a controlled thermonuclear reaction capable of generating useful power and the knowledge that it will be many years before practical systems can be developed, a number of scientists have proposed the use of *uncontrolled* thermonuclear reactions for peacetime purposes. In other words, they propose to utilize the explosive energy of the hydrogen bomb, not only as a tool for fundamental scientific investigation but also for generating electric power and stimulating chemical reactions.

In the United States, work in this direction has been carried on under the Plowshare program. This is the program in which, until the nuclear test ban, a number of underground nuclear explosions were set off in remote areas in Western United States. As is well-known, such underground nuclear explosions were also set off by Soviet scientists.

This field of research, however, is complicated by the fact that nuclear explosives have military significance as well as peacetime applications; hence, it is connected with national security and involves delicate international relations. People in general are afraid of nuclear energy — not only of nuclear explosions, but all facets of nuclear energy — and the prospect of resuming underground nuclear tests has caused apprehension in many quarters, however beneficial such tests might be. And, of course, there is ample reason for such fears. The technology which results from the application of scientific knowledge is not necessarily beneficial.

Technical knowledge gives men greater power to control their environment. Unfortunately, it does not automatically enhance their wisdom nor improve their morals. As pointed out by Henry Smyth, author of the famous Smyth Report, in his testimony at a recent congressional hearing, for 15 years we have been trying to establish a worldwide system for the control and eventual elimination of nuclear weapons.

As one step toward such a system, a step that is itself highly desirable even if no further steps are taken, we have been trying to get an agreement on the cessation of nuclear explosions. "Surely," said Dr. Smyth, "this committee, and other committees of the Congress should consider very carefully whether the use of nuclear explosions for peaceful purposes will jeopardize our efforts at international control. Virtuous assurances that such explosions are not being used for weapon development will, I am afraid, simply not be believed. . . . Let us be very sure that our peacetime use of atomic explosions will not become a disruptive force in our international negotiations."

It is obvious, then, that the proposed use of thermonuclear explosions for peaceful purposes is compli-

cated by considerations far removed from the purely technical. Others, particularly those in the Plowshare program, do not share Dr. Smyth's apprehension. They feel that the international aspects of weapons control can be worked out and that the technical aspects would receive first consideration.

Why Plowshare Began

The idea of using nuclear explosions for peacetime purposes is not new. There was some consideration of the peaceful uses for nuclear explosives even during the days of the Manhattan project and again early in the 1950's, but it was only at the end of 1956 and early in 1957 that the serious and sustained effort was begun out of which grew the present Plowshare program. Two strong factors led to this reconsideration. One factor was the invention of more sophisticated nuclear explosives, particularly those that obtain most of their energy from thermonuclear reactions; i.e., the hydrogen type bomb. The use of thermonuclear fuel reduces both the radioactivity hazard and the fuel cost, since these fuels are very much cheaper than fissionable materials.

The other factor was the development of a theoretical understanding of the phenomenology of underground nuclear explosions, which underlies many of the possible applications.

Since Plowshare was started, several underground explosions have been set off, among them the Rainier and Hardtack series.

Several underground nuclear explosions were set off under the Plowshare program before the nuclear test ban was put into effect. These have all been experimental tests, and much has been learned from them. In the same period, further developments have taken place in nuclear explosive design which have allowed the cost to be greatly reduced; when nuclear explosives are specifically made for industrial uses, their light weight and small size (a necessary requirement in weapons design) are not a dominant feature of their design. At the same time, it is pointed out, this makes them much less useful, militarily.

By reducing the fraction of the energy which comes from fission,* and by surrounding such explosives with a boron-containing, neutron-absorbing blanket to prevent the neutrons from activating surrounding materials, the radioactivity is reduced to a point where it is much less hazardous.

The proponents of such underground nuclear explosions propose a variety of applications besides that of energy production. These include research studies, chemical and isotope production, mineral recovery, excavation, and water resource development. Here only the possibility of power production is considered.

Since, in these nuclear explosions, it is possible to release thermonuclear energy on a large scale, we have the basic energy source available to us. Various ideas have been suggested for the conversion of this energy to recoverable heat. The simplest scheme is based on the observed result of underground explosions that about one-third of the energy release of the explosive is deposited in melted rock at high temperature. To this end various naturally occurring materials were analyzed, and it was concluded that salt offered perhaps the best possibility for recovering the heat energy. With the simplest concept, nuclear explosions deep in salt domes would produce large pools of molten salt. The energy could then be removed by driving some working fluid, such as water, through it to produce hot gas or steam.

Theoretical calculations indicate that by multiple firings in the same location, as much as 50 per cent of the total energy released could be recovered. Assuming 30 per cent efficiency of conversion of the recovered heat to electrical power, it is conceivable that fuel costs could be reduced to a fraction of a mill per kwh. Under present AEC charges, however, the fuel cost would be considerably higher, more like 6 mills per kwh. This compares with the average U. S. fuel cost of 2 mills per kwh.

It would be better to deposit the energy directly in steam rather than in molten salt. This would be more difficult. Such a scheme would require the excavation of a large cavity, partially filled with water. The detonation of an explosive of suitable size would result in the direct creation of a reservoir of high-temperature, high-pressure steam containing nearly all of the energy. The cavity required for such a project would present formidable practical difficulties, but the proponents of the idea believe that it merits further attention and study because of its potentially high efficiency.

The Plowshare program in this area includes high explosive and laboratory experiments, as well as considerable theoretical effort. In addition, one nuclear experiment, Gnome, is ready to go to construction. This experiment (assuming the nuclear test ban will be lifted) will be the first exploratory step in depositing the energy in salt and recovering it with a transfer fluid. According to Dr. Gerald W. Johnston, of the Lawrence Radiation Laboratory, in about two years it would be possible to perform a small-scale experiment in a cavity.

There are other reasons besides the production of power for conducting underground thermonuclear explosion research — the production of chemicals and radioisotopes. A megaton detonation releases energy equivalent to that produced by burning 150,000 tons of coal. Such detonations, moreover, are accompanied by extremely high temperatures, which effectively produce unprecedented quantities of matter in the form of free atoms. Such compounds as lime can be formed in a nuclear explosion, and the stored (chemical) energy can be tapped gradually. Temperatures of 10,000 F, which are available, form simple compounds. Elements such as aluminum and silicon will quickly form certain oxides not ordinarily existing at normal temperatures, and these might be of considerable value.

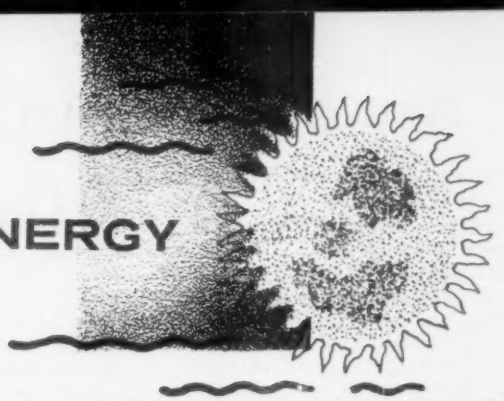
Geothermal Power

In addition to the direct conversion of thermonuclear energy into recoverable heat, consideration is being given to the use of nuclear explosions to release geothermal power. In principle, the idea is to capitalize on zones of the earth where massive high temperature rocks are near the surface. For example, if 400 C rocks are available at a depth of 15,000 ft, then an explosion could be set off to shatter the formation. The energy could then be recovered by permitting water to come in contact with the hot rock. It has been estimated that if heat is extracted in this way until the temperature of the rock drops to 200 C, the recoverable energy would be several times the energy of the explosion.

According to estimates made, to run a 500,000-kw plant from steam produced by such underground thermonuclear explosions, it would be necessary to fire a million-ton (TNT equivalent) explosion every 10 to 15 days. Alternatively, it would be necessary to deposit the energy in a large field deep underground, and recover it later. In principle, enough energy could be deposited to operate the power plant over its full life.

Dr. John Grebe, Director of Nuclear and Basic Research at Dow Chemical Co, has proposed the explosion of thermonuclear bombs in deep, nominally worthless coal deposits.* Starting with the heat of the bomb and later by the introduction of air and water, steam would be generated as long as there was anything combustible within reach.

* Thermonuclear explosives are set off by a fission type nuclear reaction. This produces the very high temperature needed to start the thermonuclear reaction.



USE OF SOLAR ENERGY

NO CONSIDERATION of new power sources could possibly exclude solar energy despite the fact that it constitutes the oldest source of energy available to man. Indirectly, solar energy has been used longer than any other kind of energy because the power of falling water, and the power of the wind, as used by man to run his early windmills and to propel his sailboats, basically, is solar energy.

Unlike nuclear energy, which is enormously concentrated, solar energy is extremely tenuous. These two sources of energy are in fact almost at opposite extremes, not only with respect to concentration but also as far as equipment complexity is concerned. Although solar energy is received at the surface of the earth at an enormous rate, it is of very low concentration and of great variability in time and place. In the United States the amount of energy received is about 2000 times our total energy requirements. The magnitude of the amount of solar energy received may be visualized by noting that the average acre of land in the United States receives about 60 million Btu of radiant energy per average day, and that in the sunniest regions, summer normals exceed 100 million Btu per day per acre.

The solar energy input is so great that all of the world's known fuels would last only a few days if they were used to produce heat at a rate to equal our solar input. In terms of power the rate of solar input is roughly equivalent to 24-hr averages of 700 to 1200 thermal kw per acre.

In contrast to these impressive figures based on an acre of ground, the figures involving smaller areas, say a square yard, illustrate the diffusiveness, or the low concentration of, solar energy. On a sunny day a square yard receives only about 25,000 Btu, or about one-fourth of a thermal kilowatt on a 24-hr basis.[8]

These figures lead us to two conclusions. First, in the energy of the sun there is ample *raw* energy for all the foreseeable needs of man, even if no other sources were available. Second, it is obvious that to capture any substantial amount of this solar energy, large surfaces must be provided to collect it.

To convert solar energy to a form that we can use, some sort of surface must be provided to intercept the radiation and convert the radiant energy to either heat, electricity, or chemical compounds. In conventional heat exchange equipment such as the tubes in a boiler furnace, heat-transfer rates of 100,000 Btu per sq ft of surface are common; indeed no commercial heat exchangers would operate at heat-transfer rates lower than several thousand Btu per sq ft per hr. Compared to these rates solar energy has a maximum intensity of only about 350 Btu per sq ft per hr, and, on the average, in a sunny region, only about 200 Btu per sunshine hour on each square foot of absorption surface.

In view of the low intensity, the need for large collecting surfaces is obvious since it is impossible to increase the solar energy rate by any artificial means. Even solar magnifiers or concentrators, such as are used in solar furnaces, can deliver energy only in direct proportion to the area they occupy.

In addition to the disadvantage of low intensity, the intermittency of solar radiation presents another problem in most applications. Not only is there the regular and predictable variation from day to night, but there is also the unpredictable variation due to clouds. Superposed on these variations is the seasonal variation of solar intensity. Thus, the use of solar energy involves three basic requirements: 1. That the need for energy supply is not continuous, 2, that there is available a source of supplementary energy, and 3 that some form of energy storage is available.

These characteristics of solar radiation do not lend themselves to the large-scale, high intensity energy applications of modern industry, and it is unlikely that solar energy will provide the energy needed in our industrial centers. However, the fact that solar energy is free and that it is available even in the most isolated and remote regions of the earth makes its possible use of great value for many purposes such as space heating, cooling, water heating, and certain other domestic purposes.

At the present time most applications of solar energy require conversion into heat at relatively low temperatures although there are a few small applications where solar energy is converted directly into electricity.

The most practicable application for solar energy, now, is for domestic space heating and for water heating, and the possibilities are attractive.

Basic elements in a practical solar heating system are a solar collector, a suitable means for storage such as insulated hot-water tanks, and a conventional furnace for meeting severe demands. According to Dr. George O. G. Lof,[8,9] a typical requirement for an average house in a sunny region would be about 500 sq ft of solar collector on the roof and heat storage in perhaps 1000 gal of water.

Two types of solar collectors are possible; one type is the so-called flat plate type which consists of a large blackened surface, usually metal, overlaid with one or more transparent surfaces to permit passage of the radiation and to reduce the escape of heat. The black surface is heated by absorbed radiation, and air or water is brought in contact with the hot surface for heat recovery. Although these units are relatively simple in design, they are too expensive for wide and general application as a source of moderate temperature heat. Most of the present development is directed toward cheapening them. The other type of solar collector involves a focusing system whereby concave reflectors receive the solar radiation and concentrate it on a small receiver which can then be used to heat air, water, or other material. Obviously, with such collectors, means must be provided to continually move the collector so as to follow the sun and keep it in focus. This requirement complicates matters, and much development work will have to be done to reduce the cost of such systems.

Energy can also be converted directly into electricity with semiconductor materials such as the silicon cell developed at Bell Telephone Laboratories. With suitable electrical connections, conversion efficiency of these cells is over 10 per cent, but their high cost ($50,000 per kw) would limit their use to radio receivers or small transmitters in satellites.

SPACE PROPULSION AND POWER

AMONG THE MANY power development concepts being considered at the frontiers of power research, those leading to the propulsion of vehicles through space are not only of consuming scientific interest but involve virtually every concept already covered in this section as well as others of such an unusual nature that they may not be applicable to any purpose other than space propulsion. Even though these concepts may not be applicable to industrial power development, it is of interest to consider briefly the nature of the work being carried on in this area.

Space vehicles thus far have been powered entirely by engines involving chemical reactions; that is, the combustion of some fuel by means of an oxidizing agent. Nuclear energy is also being considered as a source of heat in rocket engines. The application of chemical energy or nuclear energy in this case is not essentially different from the use of these energies for conventional applications.

The type of propulsion plant being considered here is the electrical space propulsion plant, in which the thrust is delivered by ion reaction, by charged colloid particles, or by some combination of these methods. Since chemical sources known today produce specific energy too low to be used effectively, the most feasible source of power for these electric propulsion systems is nuclear energy. Nuclear energy can produce the large amounts of energy at the rate required for extended space missions, and it can be applied using present techniques.

Power conversion can be accomplished mechanically, thermoelectrically, thermionically, and by the application of magnetohydrodynamics principles.* Mechanical methods, i.e., conventional turbines and generators, appear promising for applications, but other methods, ultimately, may prove more desirable if they can be developed. Steady progress is being made in the development of these methods; consequently, direct conversion devices combined with an electrical thrust chamber may make early contributions to the development of continuously powered and controlled space flight.

Electrical thrust chambers have a variety of forms. The electrodynamic thrust chamber, variously described as the arc or plasma jet, uses electrical energy for heating the propellant gas, which in turn is expanded through a de Laval nozzle to generate thrust in the same manner as a chemical rocket. Other devices generate a plasma which may be accelerated by external, or induced, electromagnetic fields. Ions can be extracted from the plasma, or formed directly from the plasma and then accelerated electrostatically. This is the ion rocket engine. A typical ion propulsion system is shown in Fig. 10.[10] Substitution of colloid particles offers the potential advantage of low specific impulse to the electrostatic ion rocket. The concepts embodied in the electrical thrust chambers are as varied as those in the power propulsion systems.

The three principal concepts are the ion concept in which ions are accelerated by electromagnetic or electrostatic fields, the magnetohydrodynamic principle, and the electrothermodynamic principle. The magnetohydrodynamic (MHD) engine is differentiated from the electrothermodynamic and ion engines by the method of accelerating the plasma. High velocities are achieved by the application of electromagnetic fields which control and accelerate the charged particles.

In the electrothermodynamic concept an electric arc is used to raise the electrons and the ions to the same temperature. This can be done provided the pressure is high enough, and this can be achieved by constricting the arc. In early exploratory work, H. Maecker and Theo. Peters in Germany injected water tangentially into a cylindrical chamber in which an arc was operating, thereby producing temperatures several times those that could be achieved by chemical reactions. The injection of various gases (argon, helium, etc) instead of water has been used to obtain high temperature and high velocities in high-temperature wind tunnels.

It is not feasible in this brief survey to describe the details of the research that is being done in this area of power development, but certain basic relationships govern the behavior of these electrical propulsion systems. The power plants involved are all reaction-type engines that generate thrust by the ordered expulsion of energetic, charged particles from the engine.

* See following article on Direct Conversion by H. M. Ogle.

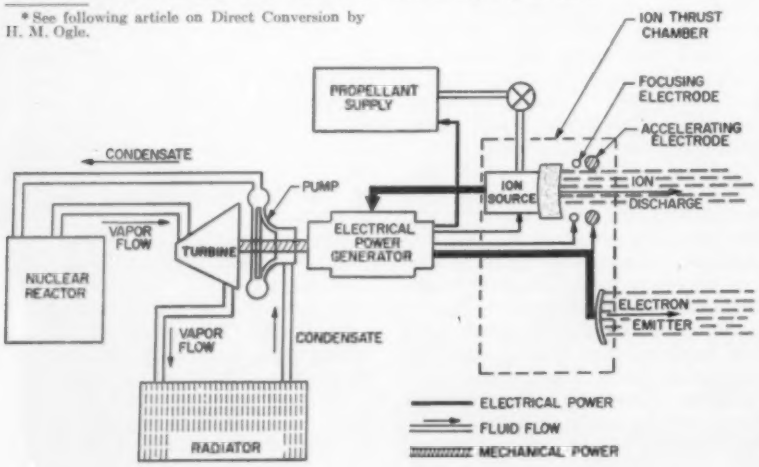


Fig. 10. Drawing at left shows typical ion propulsion system using a nuclear reactor in combination with a gas-turbine power conversion unit as the source of high-voltage electricity

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DIRECT CONVERSION

H. Malcolm Ogle, the author of this article, is a holder of 24 U.S. patents and is a veteran of 19 years service with General Electric Company, the last five years with the Atomic Power Equipment Department. A native of Maryland, Mr. Ogle was graduated from Johns Hopkins University in 1940 with a bachelor of science degree in electrical engineering. He joined General Electric in 1941 on the Company's Test Program, and later was assigned to the Company's Consulting Engineering Laboratory as a development engineer. In 1953 he was appointed manager of controls systems engineering for the General Engineering Laboratory. In June 1955, Mr. Ogle joined the Company's Atomic Products Division as a member of the Atomic Products Study team. This group was charged with responsibility for analyzing the commercial opportunities which atomic energy offered for General Electric. When the Atomic Power Equipment Department was formed and its headquarters established in San Jose, California, Mr. Ogle was named its Manager—Control and Instrumentation Engineering. He was appointed Consultant—Development Products, in February 1959, a position he held until his appointment this year as Manager—Plasma Diode Project.

Mr. Ogle is a member of the American Rocket Society, American Institute of Electrical Engineers, Tau Beta Pi, and a Senior member of the Institute of Radio Engineers. He resides with his wife and four children at 70 Jordan Place, Palo Alto, California.

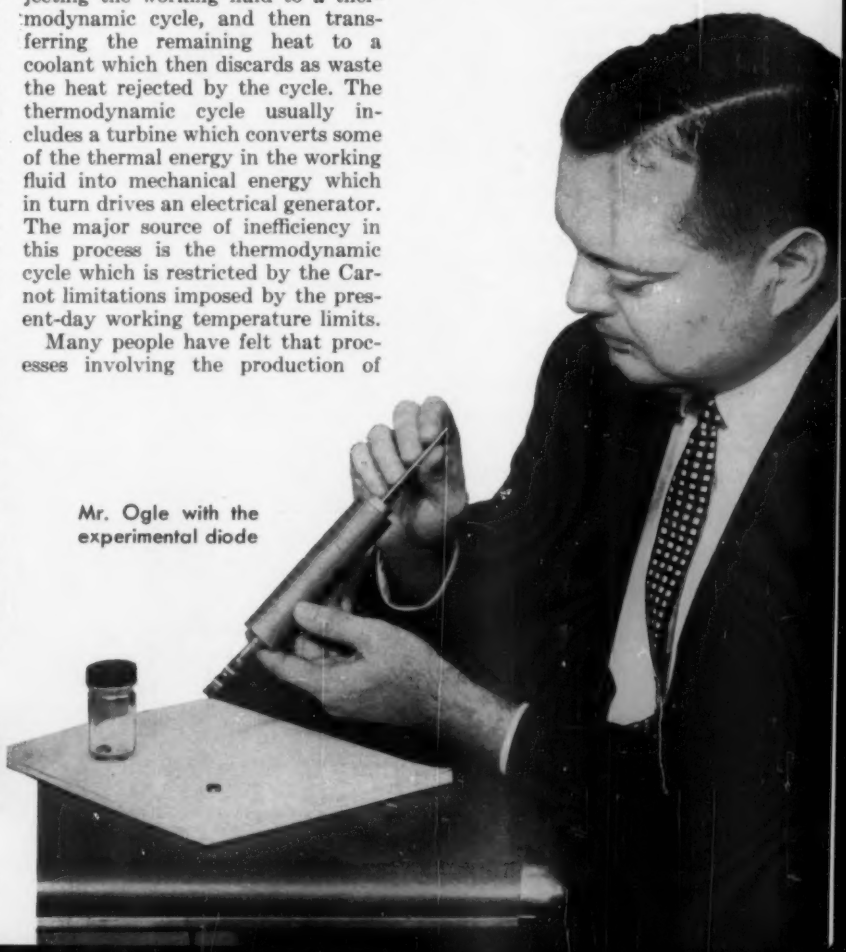
FRONTIERS IN POWER RESEARCH

SINCE the beginning of the Industrial Revolution in the 18th century, mankind has continually sought to improve the efficiency with which energy can be utilized. The introduction of large scale generation of electrical power in the first half of the present century was a major step in this direction. With improved techniques and larger installations the efficiency of electric power generation has been considerably stepped up. Today in our better plants we expect that about one-third of the heating value of our fuel can be made available as electricity to do man's work.

The processes whereby this is accomplished are well known and, in general, involve burning the fuel to obtain high temperatures, transferring the heat to a working fluid, subjecting the working fluid to a thermodynamic cycle, and then transferring the remaining heat to a coolant which then discards as waste the heat rejected by the cycle. The thermodynamic cycle usually includes a turbine which converts some of the thermal energy in the working fluid into mechanical energy which in turn drives an electrical generator. The major source of inefficiency in this process is the thermodynamic cycle which is restricted by the Carnot limitations imposed by the present-day working temperature limits.

Many people have felt that processes involving the production of mechanical energy as an intermediate step are unnecessarily complicated and that some means of direct conversion of the fundamental energy of the fuel into electricity would be preferable. This is what we mean by "direct conversion." Several methods of doing this are well known. Electrochemical, electromagnetic, thermoelectric, thermionic, and photovoltaic processes have been suggested for this conversion. Many of these methods are used on a small scale to produce electricity for special purposes. The most common of these methods is the primary battery, which is a very useful, although rather expensive, source of electrical power.

In the latter part of the nineteenth century primary batteries supplied a large percentage of the electrical power available to man. The "fuel"



Mr. Ogle with the experimental diode

consumed by these batteries is the metallic electrodes and is obviously quite expensive when compared with more conventional fuels. In more recent times the idea of using batteries with replaceable electrodes has been receiving a great deal of attention. Batteries of this type have been termed "fuel cells," and several combinations of possible chemical fuels have been demonstrated. The fuels which have been used to date, however, have been quite expensive as compared with conventional combustion fuels. As large electrodynamic machines were developed with high efficiencies, it made good economic sense to use mechanical energy as an intermediate step in the production of electricity.

Thermoelectricity was also tried as a possible competitor to batteries and in some cases was used rather successfully. In 1843 a patent was issued to Moses Poole for the use of a thermoelectric pile in place of a voltaic battery. At the end of the nineteenth century electrometallurgical processes were powered by thermoelectricity, and small gas-fired thermoelectric generators were available to replace dry cells for scientific experiments. These applications of thermoelectricity were severely limited by the low efficiency of the thermoelectric materials available at the time, but even then they were able to compete with primary batteries in some cases. Here again, however, the large electrodynamic machines driven by relatively inefficient thermodynamic cycles have proved to be a much more economic method of electric power production.

Direct conversion is therefore not a new idea. Two things have happened in recent years which have caused us to re-examine the possible importance of this field. First, good semi-conductor materials have been fabricated and their theory of operation is now well understood. Second, the higher temperatures required by thermionic processes are available as a result of nuclear fission. For some special purpose applications such as portable power supplies and power for space vehicles, direct conversion is attracting a great deal of attention today because it may provide a means of substantially reducing the weight and complexity of power plants. Applications such as these have stimulated a considerable amount of investigation of possible direct conversion systems, and in some cases these investigations have shown that substantial improvement in conversion efficiency is possible. If these higher efficiencies can be obtained together with long life and reasonable cost, they may well have a substantial impact on the technique of central station power generation.

The Incentive

Operators of central station power generation systems have always been under pressure to improve over-all system efficiency. This pressure has had its effect and substantial improvements have been made over the years. Figure 1 illustrates the gains in average efficiency which have been made in this respect in the United States. During World War II there was a marked plateau in system efficiency as installed equipment was pushed to its limit to provide the necessary capacity. The important point to note from this curve are:

1. Continuous improvement has resulted.

2. The rate of improvement has decreased in recent years.

3. There is a long way to go. A major inefficiency still exists.

It is well recognized that the outstanding inefficiency remaining in today's power plants is the Carnot limitation of the thermodynamic cycle itself. Most of the improvements in recent years have been the result of higher operating temperatures and pressures which have in turn permitted the thermodynamic cycle to operate more efficiently.

Possible Temperature Range

Reliable operation of a plant at higher temperatures and pressures can only come about after an extended period of material development, equipment development, design and operating experience. All of this development process must have a firm economic basis. It is not sufficient to know that certain materials can be operated at high temperatures. The basic cost of the material, the cost of fabrication, the design modifications required by the material characteristics, and operating costs such as those involving inspection, maintenance, and replacement must all be taken into account. Many materials are available today which can withstand temperatures considerably in excess of present power plant operating practice, but the economic problems of applying these materials to our power plants remain to be solved.

There are, of course, some fundamental limitations to the ultimate temperatures at which practical thermodynamic cycles may be operated. We have available only a finite number of elements from which to construct our alloys, and only a very few of these are suitable for high temperature operation. Among the elements which are suitable for such operation we find some of the most expensive materials known to man.

Fig. 1. Gains in Plant Efficiency

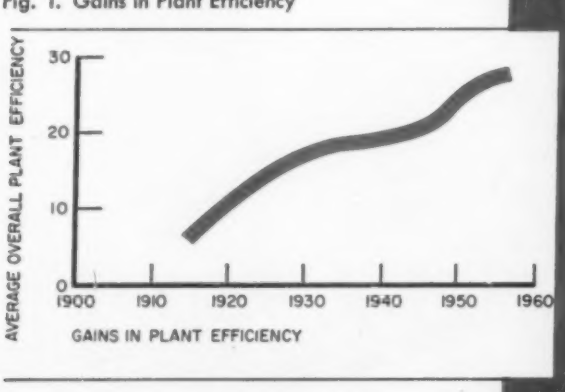
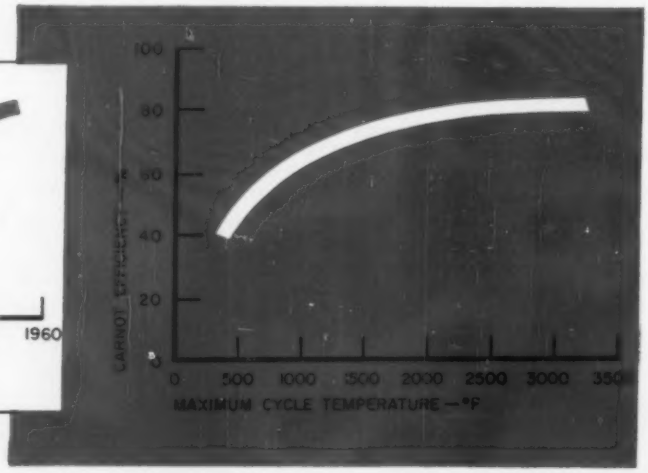


Fig. 2. Possible Carnot Efficiencies



If we are ingenious we may still find economical ways to use these expensive materials, but they obviously must be used very sparingly if at all.

Some of the more inexpensive refractory materials are quite suitable for extended operation at extremely high temperatures, but we have not yet learned how to construct practical thermodynamic cycles using these materials. Hafnium carbide, for example, has the highest melting point of any material known to man (7500 F), and ways to fabricate parts from such material are currently being developed in laboratories. Aluminum oxide (melting point 3700 F) is relatively inexpensive, and techniques for parts fabrication from this material are fairly well known. These materials and several others are known to maintain some reasonable physical properties above 3500 F. It would appear therefore that any fundamental limitation to a maximum cycle temperature because of possible materials availability would probably occur at some temperature in excess of 3500 F.

Another Limitation

Another fundamental limitation is that imposed by the theoretical combustion temperatures of economic fossil fuels. Even though an oxygen-acetylene flame has a theoretical combustion temperature of 6300 F, this combination of fuel and oxidizer is far from being an economic source of heat. More probable fuels burning in air have theoretical flame temperatures in the range of 3500 F to 4000 F. Practical flame temperatures are of course considerably lower than this. If we want this gas to heat up some solid, we must allow a few hundred degrees for the convective film drops and surface transfer coefficients. This lowers the maximum practical temperatures to 2500 F to 3000 F with economic fossil fuels. Higher gas temperatures can of course be produced by regeneration, but the high-temperature heat transfer requirements of a regenerator add significantly to the over-all cost of the high temperature gas.

When nuclear energy is used as a source of heat, the theoretical combustion temperature is no longer a significant limit. The energy released by fission of a single atom of U-235 is approximately 200 million electron volts. This is roughly analogous to a theoretical combustion temperature of fifty billion degrees Fahrenheit. Under these circumstances the fuel materials and the structural materials in immediate contact with the fuel provide the only real limit to the maximum temperatures which can be used. It is interesting to note that the temperature achieved inside the fuel elements of large nuclear power reactors such as in the Dresden Power Station is approximately 4500 F. This temperature represents a material limit selected by the designer so as to provide a long-life fuel with a reasonable fabrication cost.

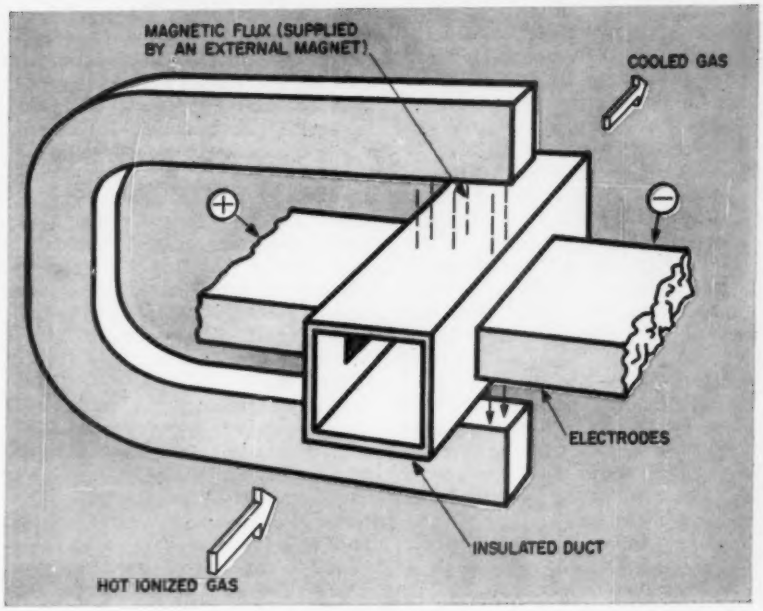


Fig. 3. MHD Generator

Will economic incentives force us to operate at temperatures much above a material limit of 3500 F? It is doubtful. In Figure 2 we see that the law of diminishing returns sets in on the available Carnot efficiency when we consider high temperatures such as these. This figure is based upon a cooling water temperature of 85 F, but it would not be significantly different for any of the usual power plant heat sinks. Power plants for space vehicles will probably have to reject their waste heat at very high temperatures and may therefore find it desirable to operate at somewhat higher maximum cycle temperatures. Even in this case the amount to be gained by higher temperature operation will tend to saturate in a manner similar to that shown in Fig. 2. From this we can see that there is a great Carnot incentive to increase our maximum temperature from 1000 F to 1500 F but very little incentive to increase our maximum temperature from 3000 F to 3500 F.

In summary there are three factors which will tend to limit the maximum cycle temperature in power plants:

1. Materials
2. Combustion Temperatures
3. Diminishing Carnot Incentive.

These three factors will in themselves tend to set a limit of about 3500 F on maximum cycle temperatures. This limit is sufficiently above present operating practice to provide an attractive range in which possible future cycles may operate.

Body Forces vs Surface Forces

In the conventional turbine the hot working fluid presses against the turbine buckets and thus produces the mechanical output torque. This pressure is produced by the surface of the hot fluid and is delivered against the surface of the bucket. Conventional cycles can therefore be described as depending upon surface forces for their operation. A characteristic of a process based upon surface forces is that the surfaces in contact must be compatible, and if long life is desired, the mechanical, chemical, and metallurgical effects which tend to destroy the surfaces must be minimized.

Direct conversion processes which are under study today are based upon body forces rather than surface forces. Throughout the volume occupied by the body of the working fluid each small spatial increment contributes individually to the electrical output. Actually the kinetic energy which

individual charged atomic particles have acquired as a result of the temperature of the fluid is converted into electrical potential by either electromagnetic or electrostatic processes. Because the lines of magnetic or electrostatic forces are unaffected by temperature, these body forces can be developed for any range of temperatures at which the working fluid may be suitable.

Mechanical, chemical, and metallurgical effects are limited to the outer surfaces of the device, and these outer surfaces may, in theory, be cooled without too great a loss of heat from the working fluid. For this reason, processes based upon body forces can work with much higher temperatures in the working fluid and may provide a way to take advantage of the potentialities of the high temperature range.

Magnetohydrodynamics

If the steam of a conventional power cycle can be replaced with a working fluid that is an electrical conductor, a magnetic field can be used to generate a voltage gradient in the moving fluid in accordance with Faraday's Law of induction. When connections are made to this generated voltage, it is possible to deliver power to an external load. This power is the result of body forces within the fluid acting against the magnetic lines of force. Such a system is known as magnetohydrodynamic (or MHD for short) power generation. A schematic arrangement of such a system is shown in Fig. 3.

Magnetohydrodynamics is broadly defined as a science concerned with fluid flow phenomena of electrically conducting fluids. Electromagnetic field theory has been coupled with fluid flow theory, and it has been found possible to develop solutions for many flow problems by means of vector analysis and advanced mathematical methods. One fluid of particular interest to the studies of MHD is the plasma, or fourth state of matter, which exists when a gas is raised to a sufficiently high temperature to produce ionization. The ionization causes the gas to become an electrical conductor, and the normal flow equations of the gas must be modified to take into account the electromagnetic coupling existing between various parts of the fluid field.

In the MHD generator electrical power is produced by moving hot ionized gas across a magnetic field so as to generate a voltage gradient as predicted by Faraday's Law. Energy required to move the gas through the magnetic field is supplied by permitting the gas to expand as though it were in a turbine nozzle.

Electrodes are provided to make electrical contact to the moving plasma, and these are used to conduct power to the external circuit. An MHD generator of this type can theoretically be made in any size. The energy contained in the very high temperature gas can be efficiently converted into electricity if the plasma resistance and electrode contact resistance can be kept low. If the duct has a reasonably large volume, the percentage of the total heat which is lost through the walls can be minimized. The walls of the ducts can even be cooled without too great a loss of efficiency if the duct is large and can therefore provide a small ratio of surface to volume. The electrodes can also be cooled in this fashion, but if the temperature of the gas immediately adjacent to the electrodes is cooled to too great an extent, the gas will lose its ionization and the generator will be open-circuited.

For this reason the electrodes in the MHD generator must be operated at high temperatures. The MHD generator in effect replaces both the turbine and the conventional generator. It must, however, be operated at very high inlet temperatures and must of necessity reject its waste heat at high temperatures close to those required for ionization. For this reason most proposals for MHD power plants have used the MHD duct as a topping device for a conventional turbine-generator cycle.

Very little is known about the life of possible materials required for the construction of the MHD duct. In addition, only a few of the many possible plasma compositions have been studied. Power production by means of a small MHD duct has been demonstrated in the laboratory, utilizing an electric arc as a source of high temperature plasma. In addition, limited tests using high temperature flames have been run. Aluminum oxide ceramics have been used for these small ducts, and other ceramic materials are being tried. Cesium and potassium salts have been added to the hot gas in order to promote ionization. (Cesium has the lowest ionization potential of all the elements and potassium has an ionization potential only slightly greater.)

Specific Problems

The problems involved in generating the very high temperatures required for this system from the combustion of economic fuel remain to be solved. Many problems also remain in the design of the duct itself, the two major ones being the need for compensation for the "armature reaction" which tends to distort the flux within the duct and the design of the duct ends so as to minimize the short-circuiting effects caused by the high conductivity of the hot plasma.

Perhaps the most severe limitation in the design of MHD systems is that imposed by materials. The MHD process fundamentally subjects materials used for duct walls and electrodes to extreme conditions. There are for all materials several maximum temperatures at which they can be successfully used. The different maxima depend upon the ambient conditions and the properties of the material being used. For example, the melting point of tungsten is 6150 F. A tungsten filament in a vacuum supported in such a way that

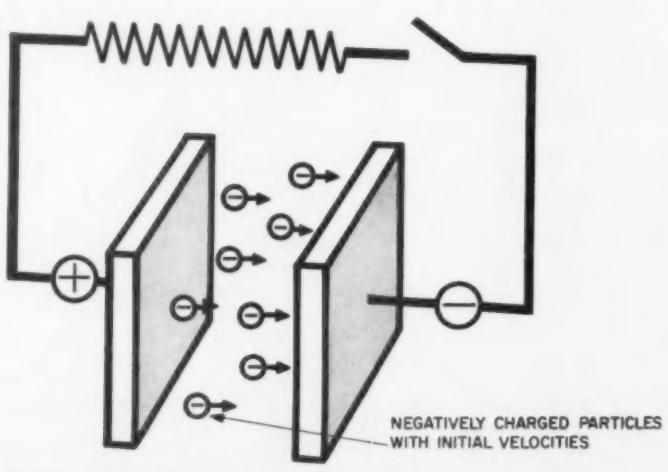
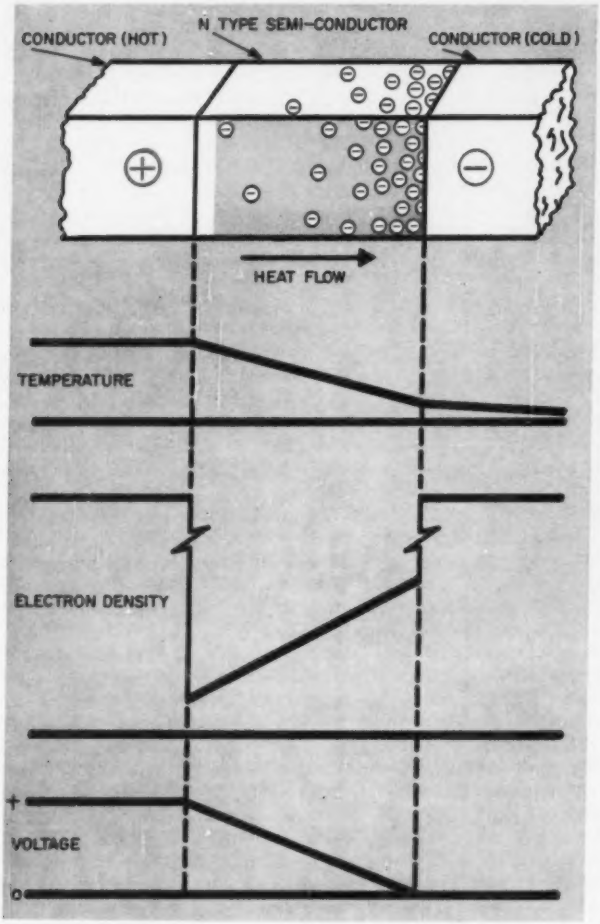


Fig. 4. Electrostatic Generator

FRONTIERS IN POWER RESEARCH



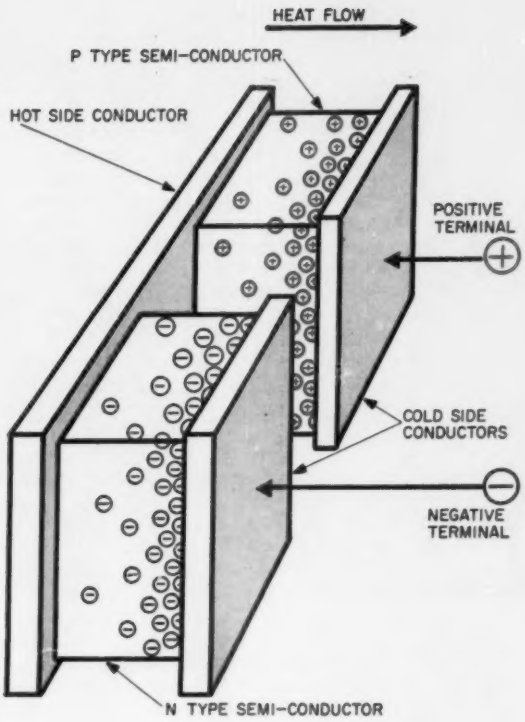


Fig. 5 (left). Thermoelectric Effect

Fig. 6 (above). Thermoelectric Generator

it is under a minimum stress will lose one one-thousandths of an inch from its surface when operated for a year at 4000 F. The same filament operated in an oxidizing atmosphere, such as air, will last only a few seconds. In air a reasonable maximum temperature for tungsten would be approximately 1200 F.

Even if chemical processes are not taken into consideration, mechanical surface erosion will greatly lower the maximum temperature at which a material can be used. These three different "maximum" temperatures for tungsten illustrate the range of practical operating temperatures for one particular material. Similar operating limits can be determined for other possible materials. In general we will find that a great difference exists between the maximum operating temperature "in vacuo" and the maximum operating temperature in an oxidizing atmosphere. The possible oxidizing atmosphere and the erosion caused by the extreme velocities make the MHD power generator a very difficult development project.

MHD generators make use of body forces pressing against magnetic flux lines to produce electricity by direct conversion. Thermoelectric, thermionic, and fission fragment collection systems use electrostatic gradients to produce body forces in the working "fluids." Systems of this type are analogous to a parallel plate capacitor as shown in Fig. 4.

Here we have two metal plates spaced a short distance apart and insulated one from the other. If an electrically charged particle in the space between the plates is given kinetic energy from some source, it will move to one of the plates and impart a charge to the capacitor. A subsequent similarly charged particle moving in the same direction as the first will have to overcome the electrostatic repulsion due to the charge on the capacitor plates. Because of this, this second particle will be slowed down and will have some of its kinetic energy converted to electric potential as it makes its journey to the plate. Each subsequent charged particle will add to the voltage of the capacitor until an equilibrium condition is established wherein the voltage is so high that no further charged particles have sufficient energy to make the journey.

If an external load is connected to this capacitor, the equilibrium condition will occur when the amount of charge flowing through the load equals the amount of charge flowing across the space between the plates. This basic method of voltage generation in which kinetic energy of charged particles is converted into electric potential is common to thermoelectric, thermionic, and fission fragment collection systems although the voltages produced by these systems are vastly different.

Thermoelectrics

The electrical conductivity of metals is due to a sea of electrons which is free to flow among the atoms making up the crystal structure of the material. The atoms in a good electrical conductor are packed closely together, and certain of the orbital electrons can pass readily between adjacent atoms. The electrons in this case are said to form a degenerate

gas, and for many purposes this degenerate gas may be considered analogous to a liquid. If one part of a metal is heated to a high temperature, this sea of electrons quickly spreads the heat by methods analogous to liquid convection currents. In other words, the sea of electrons supplies a large portion of the thermal conductivity of a metal.

In a semi-conductor there are very few electrons or charge carriers present. These charge carriers are free to move throughout the semi-conductor crystal and behave in a manner very analogous to a perfect gas. These carriers in general obey the law of perfect gases:

$$PV = RT$$

where P is the absolute pressure, V the volume, R the gas constant, and T the absolute temperature. If one part of a semi-conductor is heated to a high temperature, the charge carriers in this part will of course be at this same temperature, and they will try to establish an equilibrium with the cooler charge carriers in the cooler part of the semi-conductor. The entire piece of the semi-conductor material provides a fixed volume within which this equilibrium must be established.

In the hot region of the semi-conductor there will be few individual charge carriers, each of which has a very high velocity. In the cooler part of the semi-conductor there are many charge carriers, each of which is moving relatively slowly. In N type semi-conductors these charge carriers are negatively charged electrons, and the cooler portion of the semi-conductor will therefore acquire a high density of negative charge carriers as compared with the hot portion. The cooler region therefore acquires a negative electrical charge with respect to the hot region.

An individual electron moving from the hot region to the cold region will have to do work in order to move against the electrostatic field of the potential gradient established by this concentration of the negative charge in the cool region. Under an equilibrium condition with a steady-state flow of heat through a semi-conductor, there is a variation in the electron gas pressure from the hot region to the cold region, and this pressure change is exactly balanced by an electrical potential gradient brought about by the equilibrium charge distribution.

If a piece of semi-conductor material is arranged with a heat source and a heat sink as shown in Fig. 5, an electrical potential gradient will be produced by this effect. The same effect will occur in a metallic conductor, but because of the degenerate nature of the electron gas in the crystal lattice, the effect will be very much smaller. This effect is known as the thermoelectric effect. It occurs in all conductors and semi-conductors. The extent to which it occurs is called the Seebeck Coefficient or the thermoelectric power. If two materials having different thermoelectric powers are arranged as shown in Fig. 6, electric power can be produced. The amount of power generated depends upon the thermoelectric power of the materials and upon the amount of heat flow which is being carried by the electrical charge carriers.

Unfortunately, heat is transmitted through solid material by several different mechanisms in addition to the electronic currents. These other mechanisms in effect bypass the heat flow and make the thermoelectric generator a relatively inefficient device. A great deal of work has been done in recent years in developing semi-conductors for thermoelectric applications. Materials are now available which over a reasonable temperature range theoretically could produce electricity with an efficiency of 17 per cent. These materials have made possible the construction of small thermoelectric generators with actual efficiencies in the order of 6 per cent. In these cases most of the heat flowing from the hot to the cold junction is conducted by lattice vibrations in the crystal and thus does not contribute to the electrical output.

There are three different types of semi-conductors which can be fabricated by controlling the physical make-up of the crystal lattice. These

Fig. 7. Single Semi-conductor Thermoelectric Generator

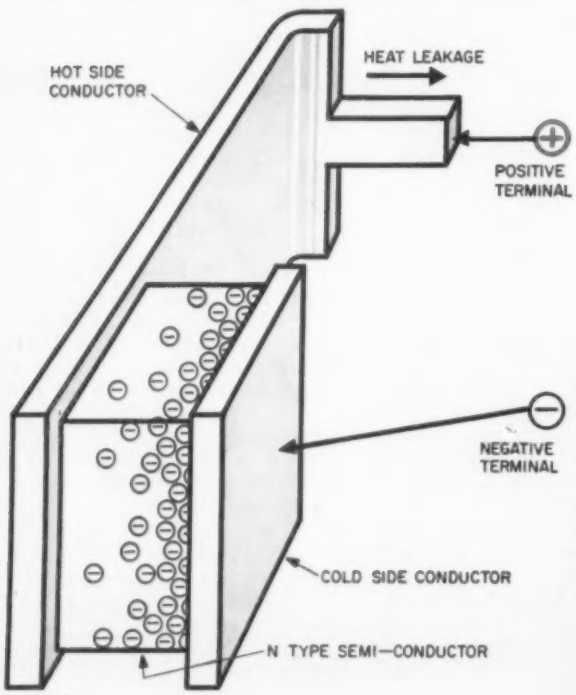
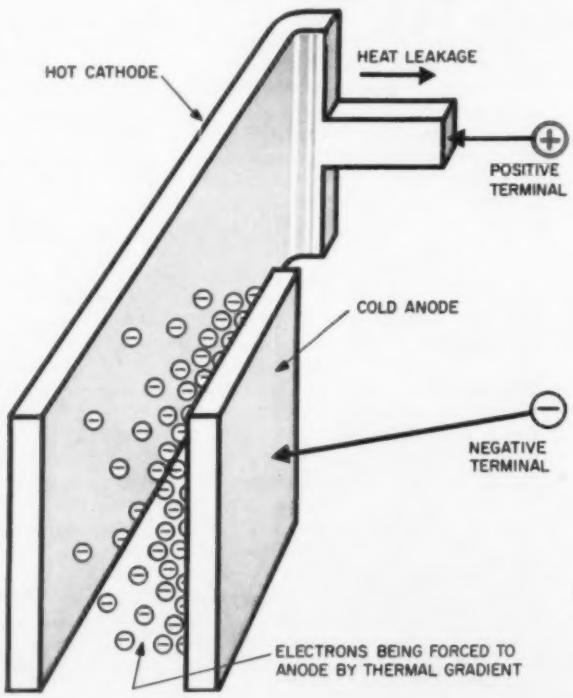


Fig. 8. Thermionic Converter



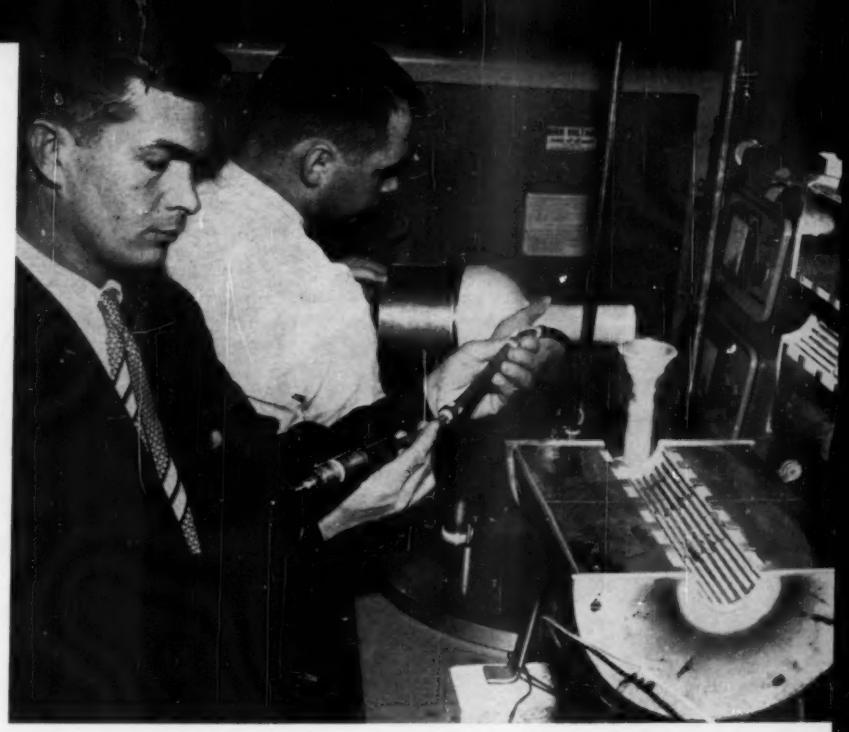


Fig. 9. A single cell Plasma Diode capsule is shown being attached to a vacuum system prior to evacuation and high temperature bake-out. Following bake-out, this capsule will be pinched off and placed in a nuclear reactor so that heat may be generated in the uranium bearing cathode

are called "N type," "P type," and "intrinsic." In the N type the lattice has a small excess number of negatively charged electrons, and these are available to act as charge carriers. In the P type the lattice has a deficiency of electrons, and these "holes" can move around like a bubble in a liquid and provide the effect of positively charged particles. These "holes" therefore act as positive charge carriers. If a lattice contains no charge carriers or an equal number of positive and negative carriers, it is called an intrinsic semi-conductor.

For a semi-conductor crystal to have good thermoelectric properties it should contain about 10^{19} charge carriers per cubic centimeter. This means that there is about one charge carrier for every two thousand atoms. If such a crystal is warmed up, more and more charge carriers will be created by electrons which have received enough energy to leave their parent atoms and move about in the lattice. This action creates both a mobile electron and the "hole" which it leaves behind. When the number of charge carriers approaches the number of atoms, the material will no longer be a semi-conductor but must be classed as a conductor. Even before this point is reached, however, the P or N nature of the semi-conductor will be diluted by the additional charge carriers, and the material will act as an intrinsic semi-conductor with very little thermoelectric power. For example, one popular thermoelectric material is bismuth telluride, which loses its thermoelectric power at 300 F.

Finding Materials

Semi-conducting materials suitable for use as thermoelectric generators are therefore restricted in their operating temperature range. To overcome this difficulty it has been proposed to make composite semi-conductors out of several materials so graded that each will work at its optimum temperature. Such arrangements will increase efficiency somewhat but will not extend the maximum temperature which can be used with a crystal semi-conductor thermoelectric generator.

Several studies have been made in attempts to find semi-conducting materials which can produce good thermoelectric properties at high temperatures and work over reasonable temperature ranges. To date several thermoelectric materials are known which can operate in the vicinity of 900 F, and at least one material (samarium sulphide) has been reported to operate at approximately 2000 F. In spite of these advances, most people working in this field are not optimistic about the possibilities of exceeding these temperatures in the near future.

Thermoelectric materials are thus limited in both efficiency and temperature range. In spite of these limitations many new uses for thermoelectric generators are being explored. Power supplies for use in outer space have been built in which radioactive isotopes are used as a source of heat. The use of a thermoelectric topping device for a conventional power plant is largely precluded by the limited high temperature range of economic materials, but a bottoming application for a steam power plant is reported to be under construction in Russia.

If only one semi-conductor material is used, it can be arranged as a thermoelectric generator by combining it with two electrical conductors as shown in Fig. 7. This type of construction is of interest when only one material is available for use in a particular temperature range. This generator will not be as efficient as that shown in Fig. 6 because here we have introduced another possible heat flow path. Heat from the source can be bypassed to the heat sink by flowing through the metallic conductor. If the cross-sectional area of this conductor is made small for a reasonable length, this heat loss can be minimized, but this necked down section of the conductor will also present a resistance to electrical load current. A good design must therefore optimize this necked down section so that neither thermal circuit losses or electrical circuit losses are excessive.

Gaseous Thermoelectrics

Nothing that has been said thus far concerning semi-conductor materials has ruled out the possibility that these materials could be in a form other than solid. As a matter of fact, studies of liquid and gaseous materials are under way in hopes that these may produce a semi-conductor suitable for use at very high temperatures. Workers at Los Alamos have designed and tested a device which they have named a "plasma thermocouple," which is an arrangement substantially the same as Fig. 7 in which a plasma is used for the thermoelectric material.

Tests have indicated that the output of this device is probably limited by the thermionic emission from the hot electrode, and if this is the case, then it could equally well be called a thermionic converter. In either case, the device is an example of a converter using electrostatic body forces

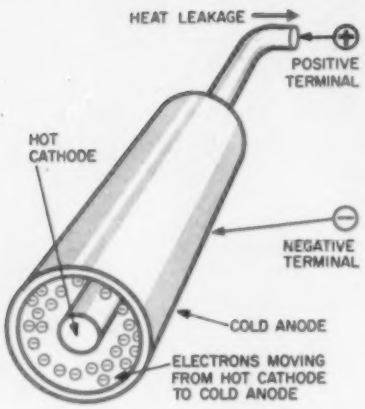


Fig. 10. Concentric Thermionic Converter—another new device

to convert energy from the working fluid into electrical potential for use in an external circuit. The working fluid in this case is of course the electron "gas" in the space between the electrodes.

When considering the difference between solids and plasmas for thermoelectric applications, it is well to keep in mind the nature of the charge carriers each contains. In a semiconducting solid the charge carriers consist of electrons and holes. The electrons have a very small mass (1/1836 that of a proton) and consequently have high mobility. The holes have effective mass mobility which is somewhat different from, but of the same order of magnitude as, electrons. It is possible to have conduction due to the presence of either electrons, or holes, or both. If conduction is due to electrons (N type material), the cold end of thermoelectric material will become negative. If conduction is due to holes (P type material), the cold end will become positive. If both electrons and holes are present in equal quantities, the material will show no thermoelectric effect.

In a plasma both electrons and positive ions are present to act as charge carriers. The electrons are the negative charge carriers and have very small mass and high mobility. The positive ions which act as positive charge carriers, however, have a large mass and a very low mobility by comparison. This mobility is determined by the particle mass. If a temperature gradient is impressed upon a plasma, most of the heat conducted through the plasma will be the result of electron motion. The cold end of a plasma thermocouple will therefore acquire a greater density of electrons and will become the negative terminal of the device.

From this we can see that there is an operating top temperature limit for any given solid thermoelectric material, and this limit will usually be somewhat below its melting point. For a plasma, however, no corresponding top temperature limit exists. Increasing a plasma temperature will not cause it to lose its basic "N type" behavior.

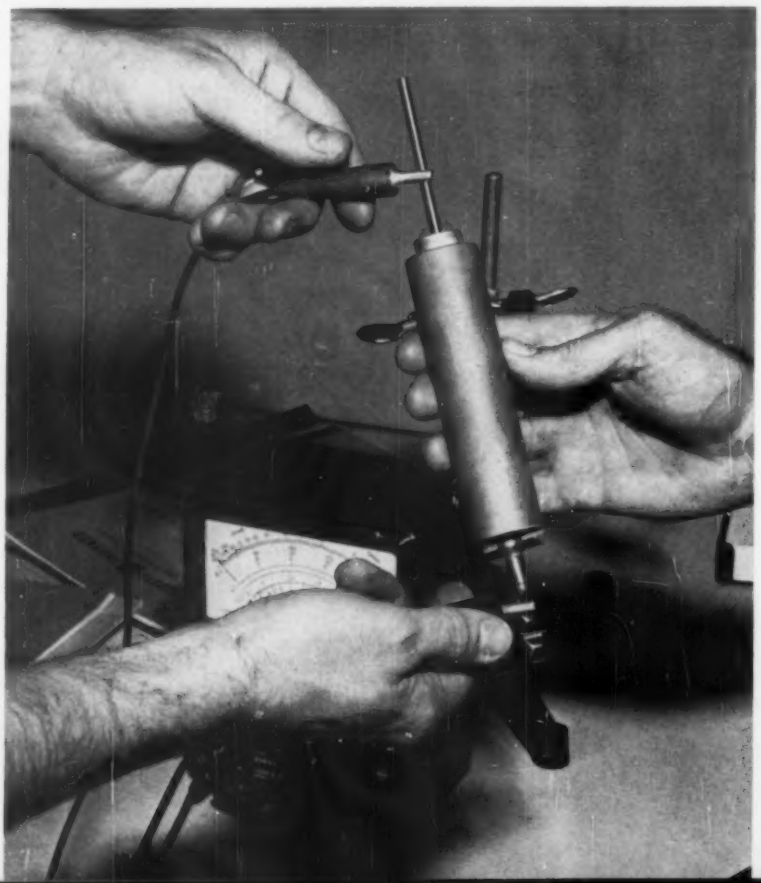
Thermionics

If a hot cathode is placed next to a cool anode and the space between the cathode and anode is evacuated, electrons from the cathode will be driven to the anode by the thermal gradient as shown in Fig. 8. This effect was first observed by Thomas Edison and has been named the Edison Effect. Because relatively high temperatures are required to give a reasonable amount of electron emission from the cathode, this device had not been considered seriously as a potential power generator until recent years. In addition to the high temperature required by the cathode, a cloud of electrons will tend to form in the space between the cathode and the anode, and this space charge will tend to limit the current output of the device.

The number of positive ions required to overcome space charge effects is relatively low. If ionized cesium gas is used in the cathode-to-anode space, a typical pressure of 10^{-4} millimeters of mercury is usually sufficient to overcome space charge effects. Tests have shown, however, that higher pressures of cesium result in greater output from experimental diodes. This increase in output has been attributed to the increase in cathode emission resulting from the presence of cesium atoms on the surface of the hot cathode. The cesium atoms appear to increase the amount of electron emission from the cathode and by this means permit larger output currents to be drawn from the cell. In addition, the cesium tends to condense on the cool anode and to coat the anode material and, in effect, this provides a cesium anode for the cell.

The work function of the anode material has a polarity which subtracts from the output voltage of the cell. As cesium has a very low work

Fig. 11. Prototype of a thermionic fuel element. This experimental fuel element is designed to produce both heat and electricity when placed in a nuclear reactor. The uranium in the cathode will contribute to the critical mass of the reactor and will produce electricity as a result of thermionic emission from the hot cathode



function, this covering helps to increase the available output voltage. Typical pressure for the cesium gas in recent experiments is one millimeter of mercury. Concentric designs such as that shown in Fig. 10 are being used to conserve the cathode heat which is being generated by nuclear fusion within the cathode. Under these conditions, cells have generated power output in excess of ten watts per square centimeter of cathode area. Most of the cells which utilize high vacuum together with close spacing to neutralize space charge have outputs less than one watt per square centimeter.

In devices being built today (see Figs. 9 and 11), it is doubtful that a uniform plasma exists across the entire cathode-to-anode spacing. In the region close to the cathode there is probably an excess of very high temperature electrons. In the middle of the cathode-to-anode space, a relatively uniform plasma exists, and in the region close to the cool anode there probably exists an insulating barrier of relatively cool un-ionized cesium gas. This insulating barrier is thin enough so that it can be penetrated without great difficulty by the energetic electrons coming from the cathode and the hot plasma.

Because this barrier will tend to act as a very thin thermoelectric material with a high Seebeck coefficient, much of the cell voltage may be generated in this region. The high-pressure plasma diode appears to be the best direct conversion device for high temperature operation. Studies are under way in many laboratories (see Fig. 12) in attempts to find the best combination of materials for cathode, anode and plasma and the best configurations for specific applications.

Fig. 12. Thermionic cathode study by means of electron bombardment. Under the vacuum bell jar, high temperatures are produced by means of electron bombardment. These high temperatures can be measured by the optical pyrometer in the foreground; effects of high temperatures on emission characteristics can be observed

Photovoltaic Cells

Photovoltaic devices such as the old selenium cells and the more recent silicon "solar batteries" provide a means of directly converting electromagnetic radiation into useful electricity. These devices can be regarded as a form of electrostatic generator, such as that illustrated in Fig. 4, in which the initial energy is imparted to individual electrons by incoming electromagnetic waves. Because the incoming waves must penetrate the active volume of the cell, this is usually made in a very thin layer and the materials used for the electrode and the active semi-conductor must be such as to permit a reasonable penetration.

Efficiencies of the old "barrier layer" photocells made from copper oxide and selenium were generally less than 3 per cent. Development of the transistor has stimulated the production of very pure single crystal germanium and silicon. These materials make excellent photovoltaic cells, and efficiencies of 12 per cent can now be obtained from cells made on a production basis. These cells are excellent for the conversion of sunlight into electricity.

It has been proposed that large banks of such cells could be illuminated by the infra-red and visible radiation from a man-made "artificial sun." This sun could in theory be a small nuclear power reactor which is cooled by radiation. Unfortunately the spectral distribution of the radiated energy and the poor utilization of the received energy of some wave lengths would cause such a system to have a low over-all efficiency. Future development of photovoltaic devices having both high efficiency and a wide spectral response may well bring about renewed interest in this approach to power generation.

Fission Fragment Collection

When nuclear fission occurs, the fissioning atom splits into two large pieces and a few small fragments. Most of the energy released by the fission process is contained in the kinetic energy of the two main fragments. These large pieces are in effect nuclei of medium weight elements such as zirconium and barium. Because these nuclei have not as yet had the opportunity to pick up electrons and thus become neutral atoms, they possess very strong positive charges. These rapidly moving positively charged particles can theoretically be used as a direct source of electrical energy in a manner similar to that illustrated in Fig. 4.

If an electrode is covered with a very thin film of fissioning atoms, many of these positive ions will be thrown off from the surface. If another electrode is placed nearby so as to collect these positively charged particles, it will soon build up to

a very high potential (in the order of two million volts) as a result of the charge and the kinetic energy of the arriving particles. When coupled to a suitable high impedance load, such a device can theoretically deliver a useful output.

Direct collection of the fission fragments is an attractive concept because the energy is collected while the particle motion is still well ordered and before thermalization of the particle motion has taken place. Under these conditions Carnot limitations do not apply, and there may be ways to design the device so as to produce very high efficiencies. If this can be done there will be very little waste heat to reject from the process. Because no part of the system need operate at a high temperature, the designer has a wide choice of possible construction materials. Offsetting these advantages are the problems involved in maintaining very high insulation resistance in the presence of the very intense radiation being given off by the fissioning atoms.

Being a very high impedance device, leakage currents must be kept exceedingly small if any useful output is to be obtained. Designs which have been proposed to date have had an additional disadvantage in that at least half of the original energetic ions from the fission process are absorbed by the negative electrode, and their energy will be converted into heat which must be removed. This results in a maximum efficiency of less than 50 per cent in all of the devices thus far proposed. In spite of this limitation both theoretical and laboratory work is currently under way in an attempt to explore the possibilities of fission fragment collection as a possible source of electric power.

Common Technical Problems

All of these methods of direct conversion are faced with very difficult technical problems, and many of these problems are common to all of the methods. Foremost among these problems are the electrical and physical properties of the plasmas and solids which are used. Data on the electrical conductivity and the thermodynamic properties of possible plasmas is very scarce. Even for the solid materials which are needed for electrical conductors, insulators, and vacuum tight enclosures, very little data is available on their electrical and mechanical properties when used in the presence of the various possible plasmas.

Some of the materials which make up these devices must be operated at very high temperatures and high heat fluxes. As most of these temperatures and heat fluxes are beyond the range of present engineering practice, exact knowledge of their probable performance is lacking. When these materials are used in the presence of other materials with which they may combine chemically, another series of unknowns is introduced. In the past there has been very little incentive to develop materials especially suited for such applications, but today the incentive is recognized and the search is on.

When nuclear fission is used as a source of heat, the fission products produced cover a wide range of atomic weights. At high operating temperatures many of these elements thus formed readily diffuse through the fuel material and other materials which are present. These various elements are therefore available to attack chemically the various parts of the structure and to embrittle or corrode the various structural materials. Some of these fission products are in the form of gases which will tend to dilute the plasmas and change their properties.

Over the lifetime of a direct conversion device used with a nuclear heat source, it will be exposed to a large number of these tramp atoms, and many changes are bound to take place. As many of these changes are probably detrimental to the efficiency and life of the device, some provision will have to be made for the periodic replacement of the direct conversion units. This consideration strongly suggests that the conversion element be coupled to the fuel elements so that when the reactor is refueled, the conversion elements will also be replaced. This periodic replacement of the conversion elements will obviously add to the cost of any power generated, but in view of the materials which are available today, designs which permit an easy periodic replacement of converter elements would appear to be prudent.

Power Density vs Economics

Studies of the application of nuclear energy to power generation have many times demonstrated the strong dependence of the over-all economics of operation on the power density which can be realized in the reactor core. If a given plant design is modified to give the same power output with reduced power density, several things will occur. More fuel will be needed, a larger pressure vessel will be required, the volume of the required shielding will increase, and the containment structure will be larger and more expensive. All of these factors force the designer to utilize the highest power density which he can obtain with reasonable fuel life.

Present designs of water-cooled power reactors produce about 100 watts of heat for every square centimeter of fuel element surface. For a direct conversion device to be of economic importance it must be within an order of magnitude of this figure. The plasma-filled thermionic diode and the MHD generator are the only devices thus far proposed which appear to have the potential of realizing this power density.

Future Work

Although much new information is needed to help solve these common technical problems, a surprising amount of related data already exists in published technical literature. Light bulb manufacturers have developed filaments and supporting materials which can operate for extended periods of time at the high temperatures required for direct conversion devices. Vacuum tube manufacturers have developed vacuum tight ceramic to metal seals which are needed to conduct electricity out of such devices. High temperature fuel materials for nuclear reactors have been the subject of intensive investigation by reactor manufacturers and government laboratories during the past decade. A combination of these techniques with the cathode and plasma data which is now being measured may well result in a practical direct conversion system.

During the eighteenth century Horace Walpole coined a word "serendipity," based upon a fairy tale about "The Three Princes of Serendip," in which the heroes were continually finding new values in articles which they discovered. This word "serendipity" means in effect the ability to find valuable applications for things by using them in an unexpected manner. It is this ability of serendipity which is required today to exploit fully the field of direct conversion. Here is where future work is most required. Engineers have demonstrated their abilities to create and work with high temperatures. Scientists have shown that direct conversion is possible. When the results of these activities have been successfully combined, direct conversion may well become an important source of electrical power.

FUEL CELLS

THEIR PRINCIPLES, HISTORICAL BACKGROUND, TYPES, AND PRESENT APPLICATIONS

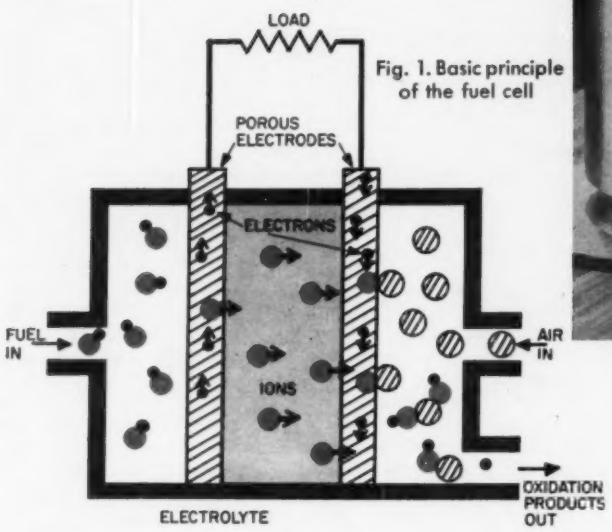
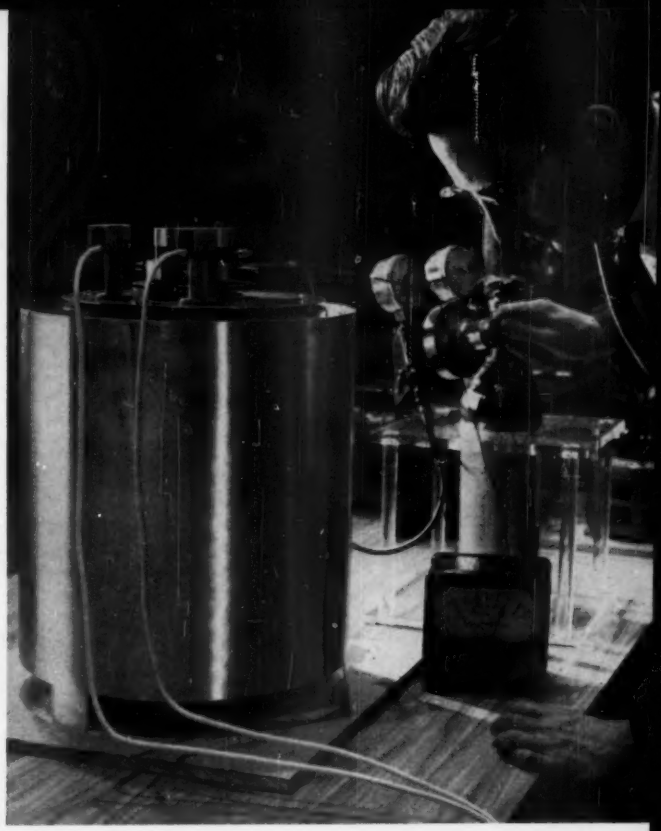


Fig. 1. Basic principle of the fuel cell



Dr. R. J. Ruka, a scientist at the Westinghouse Research Laboratories, beside furnace in which a new high-temperature experimental fuel cell is being tested

NEARLY ALL of the unconventional methods of generating electricity considered in the preceding pages are hampered in various degrees by limitations set by Carnot's Law. This Law, which applies to all heat-engine generators, states that the maximum efficiency that can be obtained from any heat engine is the difference between the input and output temperatures divided by the input temperature. Expressed as a formula, it is:

$$E = \frac{T_1 - T_2}{T_1}$$

In this formula, the temperatures are in degrees above Absolute Zero, −460 F or −273 C. Since no practical heat engine can operate below ambient temperatures, the Carnot Law means that in any such engine a large share of the original chemical energy of whatever fuel is used must be rejected as waste heat.

Unlike heat-engine generators, conventional or unconventional, the fuel cell, now to be considered, is not limited by the restrictions of the Second Law of Thermodynamics inherent in the Carnot formula. Theoretically, a fuel cell could operate at 100 per cent efficiency, but practical fuel cells operate with efficiencies of from 60 to 80 per cent, at least, and these values seem a reasonable goal. These efficiencies compare with the best efficiencies of 40 to 45 per cent of our most advanced steam-electric power plants.

Historical Background

Among the various new methods of power generation presently under investigation, the fuel cell is perhaps the one of most intense interest to the greatest number of scientists investigating new power systems. It is the subject of scores of research projects in as many countries. For high efficiency the continuous feed fuel cell is a most promising device. Yet there is nothing new about the idea. Various people have been trying to develop fuel cells on and off since the idea was first advanced, over 150 years ago, but only recently have they been able to make the idea work.

As early as 1801, Sir Humphrey Davy in England devised a fuel cell using carbon and nitric acid. In 1839, another English investigator, Sir William Grove, constructed a chemical battery in which the water-forming reaction of hydrogen and oxygen generated an electric current. Fifty years later — around 1889 — Ludwig Mond and Carl Langer developed another cell of a similar nature which they actually called a *fuel cell*. They obtained an output of 6 amp per sq ft of electrode surface.

At that time, Edison was in the process of developing his electric light system, and the success of that development overshadowed all efforts to produce power by other methods, including fuel cells. Although attempts to develop a fuel cell continued spasmodically through the years, it was not until the end of World War II that the present active research on fuel cells began in earnest.

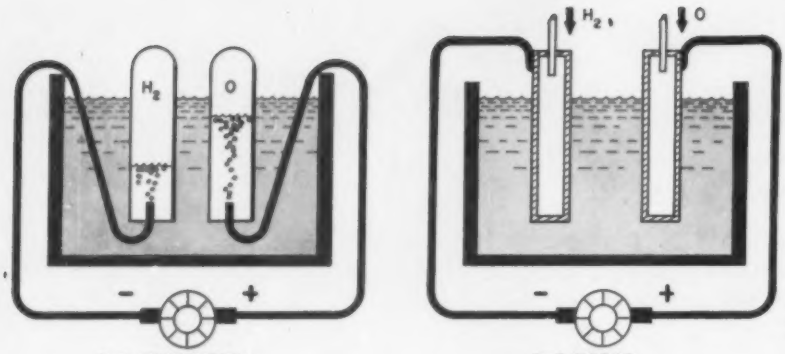


Fig. 2. Hydrogen-oxygen fuel cell operation is a reversal of water electrolysis

Now, just what is a fuel cell? A fuel cell is basically an electric battery that uses inexpensive fuels that are continuously fed into the system. Ordinary batteries, under this definition, are not to be considered as fuel cells, even though they convert chemical energy directly into electricity, because they use expensive fuels such as zinc, lead, mercury, etc. Actually, the operation of a fuel cell is just the opposite to that of a battery because the latter splits the electrolyte into its components whereas the basic fuel cell combines hydrogen and oxygen to form water, releasing electrons in the process. Energy is released in the formation of water from its constituents, whereas energy is expended in its decomposition.

The fuel (the electrodes) in an ordinary battery is expensive because a considerable amount of energy has to be expended in refining the fuel materials. This energy has to be supplied by the burning of fossil fuels or from hydroelectric power sources. A fuel cell, on the other hand, uses the basic fuel directly or almost directly.

The basic principle of the fuel cell is illustrated in Fig. 2. It is something like a storage battery in that it has positive and negative electrodes immersed in an electrolyte, but instead of having to be recharged periodically, the fuel cell generates electricity as long as the fuel (hydrogen, propane, etc) and air are fed into it. At one electrode, molecules of fuel release electrons, which then begin flowing through the external electrical circuit. With the release of electrons, the molecules become ions, which move through the electrolyte to the other electrode. There, the ions combine with oxygen and with the electrons returning from the external circuit.

Development Difficulties

The idea is fundamentally quite simple, but the development of a commercially practical fuel cell involves difficulties which have to be solved before complete success is attained. One of the difficulties stems from the initial energy needed to bring about the chemical reaction between hydrogen and oxygen to form water. The reason hydrogen and oxygen burn to form water is that, separately, these elements possess more energy than they do when combined in the form of water. This is why energy is released in the form of heat in the process of combustion. However, before any fuel can be made to burn, it is necessary to raise its temperature to the ignition or activation temperature. That is why a mixture of hydrogen gas and oxygen in a closed vessel will not burn at ordinary ambient temperatures. But if a high temperature is introduced as by the sudden discharge of an electric spark, the mixture will explode.

What happens is this: Normally, at ambient temperatures, the molecules of hydrogen and oxygen in a mixture of these two gases are in a state of thermal vibration. The speeds of the molecules is a function of the temperature or perhaps, to put it more correctly, temperature is a manifestation of the molecular activity. Some of the molecules move faster than others but none of them have sufficient speed, or energy, to reach the value where an oxygen molecule and a hydrogen molecule will combine to form water. This requires an energy equivalent to a temperature of around 900 F.

When a spark, electric or otherwise, is struck in such a mixture, the energy imparted to the molecules of hydrogen and oxygen in the immediate vicinity of the spark is high enough to cause them to combine to form water, with the consequent release of energy. This energy is imparted to other nearby molecules, which in turn undergo the H_2O reaction. Since the mixture of the two gases is uniform and intimate, the resulting chain reaction is extremely rapid and proceeds with explosive violence.

Essentially the same chemical reaction occurs in a hydrogen-oxygen fuel cell, but the energy is converted directly into electricity without the wasteful intermediate conversion of energy to heat. The operating principle of the hydrogen-oxygen fuel cell is simply a reversal of the electrolysis of water. In the electrolysis of water, a current of electricity (that is, a stream of electrons) is passed through water under the action of an externally applied potential. As a consequence, by virtue of the energy so imparted, the molecules of water are broken up into molecules of hydrogen and oxygen. In the fuel cell, the reaction of hydrogen and oxygen results in the formation of water and the

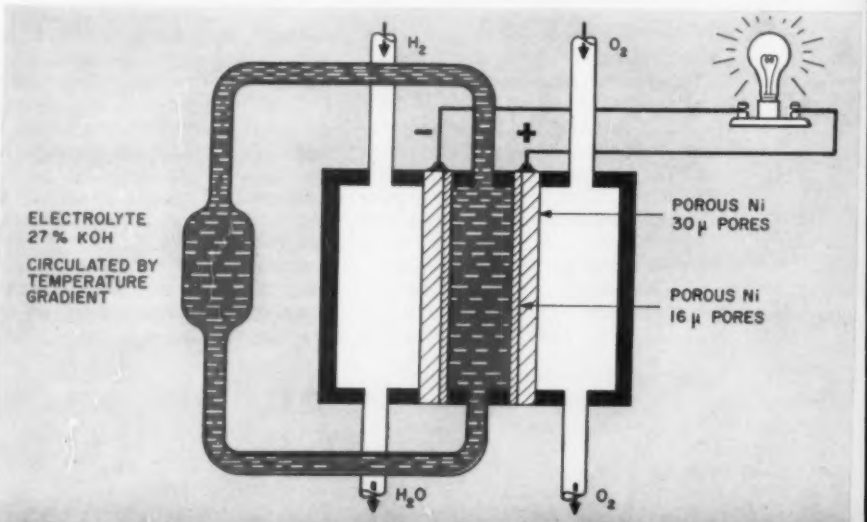


Fig. 3. Principle of the Bacon high-temperature fuel cell

liberation of a stream of electrons, which constitutes the electric current. In the first reaction (electrolysis) energy is expended, in the second, energy is liberated.

The reaction resulting in the formation of water in the fuel cell takes place in a number of steps. Each step requires an amount of energy lower than the total activation energy. Thus, instead of the 900 degree temperature mentioned previously, the O-H reaction takes place quite rapidly, even at room temperature.

One of the essential steps in the fuel cell reaction is the transfer of electrons from the negative terminal of the cell to the positive terminal through the external circuit. This flow of electrons is the electric current, the useful output of the cell. This represents a large proportion of the original potential chemical energy.

A practical fuel cell consists of two porous electrodes separated by an electrolyte, such as a solution of potassium or sodium hydroxide. At the cathode, hydrogen molecules (H_2) diffuse through the porous structure and are adsorbed on the surface in the form of hydrogen atoms (H). The hydrogen atoms react with hydroxyl ions (OH^-) in the electrolyte to form water. The amount of water formed is simply the combined weight of the oxygen and hydrogen consumed in the cell reaction. At the anode side of the cell oxygen (O) diffuses through the electrode and is adsorbed on the surface. Here, by virtue of a catalyst in the electrode, the adsorbed oxygen, the water in the electrolyte, and the electrons react to form hydroxyl ions. The latter then migrate through the electrolyte to the cathode. The reactions taking place are as follows:

Cell reaction	$O_2 + 2H_2 = 2H_2O$	(1)
Anode Reaction	$O_2 + 2H_2O + 4e = 4OH-$	(2)
Cathode reaction	$2H_2 + 4OH^- = 4H_2O + 4e$	(3)

The electrolyte is an essential part of the fuel cell because it acts as a barrier to the molecular forms of fuel and oxidant. If they came into contact, they would react chemically to produce heat. With the electrolyte acting to prevent chemical reaction, the ionization of the elements at the electrodes liberates the electrons which flow through the external circuit.

Exciting Possibilities

This, briefly, is an explanation of the basic action of a fuel cell. Unlike the thermoelectric and thermionic devices described by Mr. Ogle in the preceding article, the fuel cell is not a heat engine. It is a battery and is limited only by chemical reaction principles in which two chemicals are fed into a cell where they react and produce an electric charge and a chemical by-product (water in the case of the oxygen-hydrogen cell described). Theoretically this can approach 100 per cent, and efficiencies as high as 95 per cent have been obtained under laboratory conditions. Hydrogen-oxygen fuel cells have been operated continuously for as long as 5 years at low output levels.

Dozens of variations of fuel cells exist utilizing a variety of chemicals. The most exciting possibility is a fuel cell which would use conventional petroleum products and air as fuel, and several companies have such cells in early stages of production. The general scheme is to use catalysts in the electrodes which would separate hydrogen from the hydrocarbons and use the oxygen in the air as the oxidant. Such cells have been demonstrated with efficiencies better than 35 per cent at low temperatures, and up to 75 per cent at higher temperatures.

At moderate reaction rates, that is when the resistance of the external electric circuit is high and the current low, a large portion of the energy in a fuel cell is released as electricity; little is lost as heat. At all times, however, a part of the total energy is used in bringing the molecular energy up to the activation levels, and this appears as heat within the cell. The reason for using catalysts in the electrodes is to lower the activation energy required and thus reduce the amount of heat generated. Energy is also expended in forcing the gas molecules through the electrodes, and to overcome the resistance of the electrodes themselves. Because of these losses, the actual fuel cell voltage is below the theoretical voltage as calculated.

Basic Types of Fuel Cells

There are two basic types of fuel cells — the direct and the indirect. In the direct cell a primary fuel such as carbon reacts with oxygen. However, since neither carbon nor oxygen ionize readily at low temperatures, the high temperatures required for the operation of such cells impose a number of complex problems.

The indirect cell is the type already described in which hydrogen and oxygen are used as fuel, and the practical development of this cell has shown the greatest progress. The most advanced fuel cell and the most

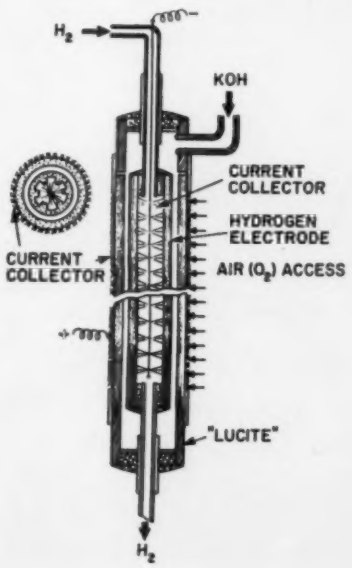


Fig. 4. Concentric tube type of Union Carbide low temperature fuel cell

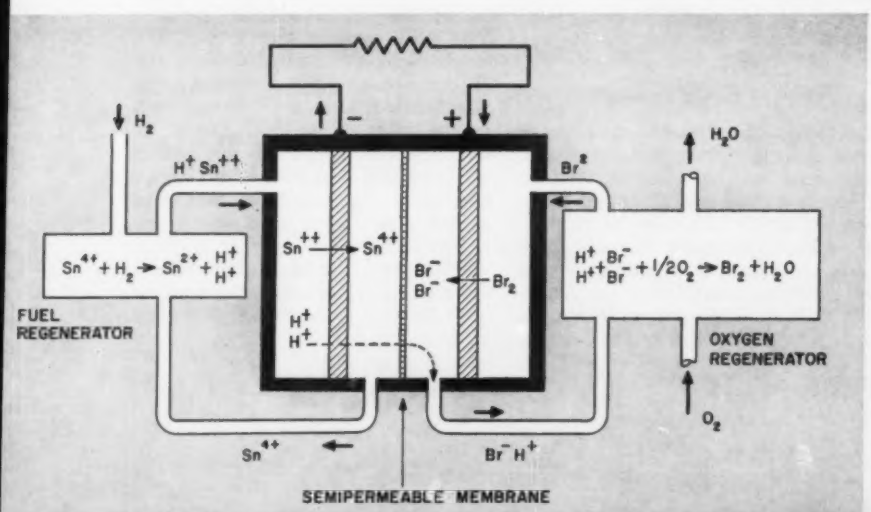


Fig. 5 (below). Operating principle of the Redox cell, described on page 70

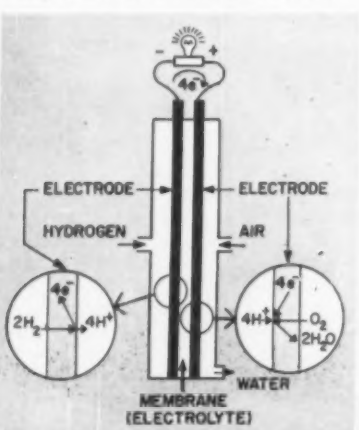
Fig. 6. **Some Known Participants in Fuel Cell Research**

	General Electric	Union Carbide	Westinghouse	Esso	Gulf	Allis-Chalmers	Consolidation Coal	Siemens & Halske (Ger)	Posner	National Carbon	Nat'l R & D Corp. (G.B.)	Technische Hochschule (Ger)	Exide	Signal Corps	O.K. Davyttan (U.S.S.R.)	Sondes Place Res. (G.B.)	Kings College (G.B.)	Lockheed	Aero-Jet	RCA
Hydrox																				
Acid electrolyte																				
Low temperature and pressure						X														
Low-temperature ion exchange	X																			
Alkaline electrolyte																				
Low temperature	X								X		X	X	X							
Intermediate temperature		X								X										
Redox																				
Acid electrolyte																				
Low temperature	X															X	X			
Molten Salt (carbonate)																				
High temperature	X						X	X			X			X	X					
Carbox																				
High temperature			X						X											
Carbonaceous																				
Acid electrolyte																				
Low temperature	X			X	X															
Alkaline electrolyte																				
Low temperature	X			X		X														
Other	X								X									X	X	

compact power source of this kind is the Bacon cell, developed in England by F. T. Bacon. Mr. Bacon and a group of associates at Cambridge University have been working on the development of this cell for some 20 years under a sponsored project.

In the Bacon cell the reactivity is maintained by operation at temperatures ranging from 392 to 468 F, with hydrogen and oxygen at pressures between 600 and 800 psi. This type of cell is known as the Hydrox cell. The principle of the Bacon cell is shown in Fig. 3. Each cell consists of two porous, sintered nickel electrodes with a thin layer having a smaller pore size on the electrolyte side. The electrolyte is a 27 per cent solution of potassium hydroxide. The electrolyte soaks into the sintered metal, and when the gas is admitted under pressure to the back of the electrode, the liquid is forced out of the larger pores only. The surface tension of the liquid prevents the gas from escaping through the smaller pores.

Fig. 7. G-E ion-membrane fuel cell



At the oxygen electrode, hydroxyl ions are formed, removing electrons and leaving the electrode positive. At the hydrogen electrode, hydroxyl ions combine with hydrogen to form water, giving up electrons in the process. As a consequence, the hydrogen electrode becomes negatively charged with respect to the oxygen electrode, and a current is established in the external circuit. To remove the water formed, the hydrogen is circulated past the back of the hydrogen electrode, and the mixture of hydrogen and steam is cooled outside of the cell to condense the moisture.

The Bacon cell produces six times as much power per cubic foot as a low-temperature hydrogen-oxygen fuel cell. It can deliver as much as 150 watts per pound, as compared to 10 watts per pound for a lead-acid storage battery. With pure hydrogen, the Bacon cell has run as long as 1500 hr, the life of the oxygen electrode apparently being the limiting factor. Efficiencies up to 80 per cent have been reported. These cells are well adapted for specialized military services and possibly for certain civilian applications, but they are not considered as a possible major power source because the high cost of the fuel outweighs the advantages.

Other Developments

Another fuel cell of considerable interest is the hydrogen-oxygen cell developed by the Union Carbide Consumer Products Company. The Union Carbide cell operates at temperatures of 70 to 150 F and at pressures ranging from atmospheric to a few atmospheres.

A fuel cell of considerable interest is the Redox cell, which derives its name from the reduction and oxidation process involved in its operation. In this cell the fuel and oxygen do not react directly with each other. Instead, the fuel and oxygen are made to react with other substances in *regenerators* outside the cell to produce chemical intermediates, which in turn generate current in the cell. The over-all reaction is the same as that of combustion, however, because the intermediates are regenerated. In the United States the General Electric Co has been using a titanium-bromine intermediate with impure hydrogen as fuel. At Kings College in London, a similar system using a tin-bromine intermediate is being investigated.

A schematic diagram of the Redox cell is shown in Fig. 5. This cell utilizes tin salts and bromine intermediates. The fuel reduces (adds electrons to) tin ions, which release the added electrons to the negative electrode and return to react with more fuel. The oxygen on the other hand oxidizes (removes electrons) bromine ions, converting them to bromine which then takes up electrons from the anode and returns bromine ions for regeneration. It will be noted that the two halves of the cell are separated by a semipermeable membrane to keep the bromine from mixing and reacting with the tin or titanium ions. One of the difficulties of the Redox cell is that all known permeable membranes possess considerable resistance, and this limits the output.

Of interest in recent fuel cell technology is the ion-membrane cell of the General Electric Co, shown

schematically in Fig. 7. This cell is classified as a hydrox-acid electrolyte type cell. The maximum power density of this cell occurs at approximately 0.55 v and at a current density of approximately 43 amp per sq ft of electrode surface.

One of the first actual demonstrations of the practical application of fuel cells in the United States was made by Allis-Chalmers in October 1959 (see POWER ENGINEERING, Dec. 1959, p. 85). In this demonstration a tractor powered by fuel cells pulled a multiple-bottom plow through average Milwaukee county soil, starting from a standstill without hesitation or jerking. This tractor was powered by a battery of 1008 fuel cells using a mixture of gases, largely propane and oxygen. This battery supplied current to a 20-hp standard Allis-Chalmers electric motor. Total electrical output of the cells was 15 kw.

It is not feasible in this necessarily brief discussion of fuel cells to describe the details of all the various types under study, but the chart, Fig. 6, indicates the principle types and the various organizations concerned with their development. Westinghouse and also Posner are investigating the merits of the Carbox cell. In this cell the fuel is carbonaceous, such as natural gas, kerosene, vaporized gasoline, or coal gases. Since the cells work at around 1200 F, the electrolyte is a molten salt, usually carbonates of sodium, potassium, and lithium. The fused mixture may be contained in a porous, nonconducting MgO matrix. The fuel reacts with steam and carbon dioxide to produce hydrogen and carbon monoxide. These react with carbonate ions to form carbon dioxide and water, giving up electrons. At the positive electrode, oxygen or air takes up the electrons and reacts with carbon dioxide to produce the carbonate ions.

This type of fuel cell offers perhaps the best promise for large-scale power generation. For special applications, for military purposes, or for space vehicles, the factors determining the cost of electricity are relatively unimportant compared with such factors as compactness or light weight. In the case of central station applications on the other hand, power cost is of paramount importance. On the basis of fuel costs, the high-temperature carbonate fuel cell seems best adapted to central station power generation. These cells use carbonaceous gases and operate at atmospheric pressure at temperatures ranging from 900 to 1600 F.

A further advantage of this type of cell is that it uses air as the oxidant rather than oxygen. Although it is difficult to estimate power or fuel costs at the present time, the fuel cost for molten salt-type cells operating on natural gas might be less than 2 mills per kwh. The development of a fuel cell for central station use, however, is still in its early stages, and it is not to be expected that fuel cells will replace conventional electric-generating equipment in the foreseeable future. At the moment stress is on military applications and on possible low power mobile use in industry.

The most complete and exhaustive analysis of fuel cell technology that has been made to date is a report, "Fuel Cells: Power for the Future", recently released by Fuel Cell Research Associates, PO Box 157, Cambridge, Mass. It is available at $18.50 and to those actively interested in fuel cells, is well worth reading. THE END

CONVERSION OF DC TO AC

IN ADDITION TO the difficult problems inherent in the various unconventional systems of electric power generation considered in the preceding pages, there is one problem that is common to all of them. This is the problem of d-c to a-c conversion. At the present state of the art, all of the systems being investigated produce electricity in the form of direct current. It is conceivable that magnetohydrodynamics might one day produce alternating current, but at present all of the unconventional power systems generate direct current, most of them at low voltage. If a practical controlled thermonuclear power system is ever developed, the chances are good that it would produce alternating current, but success in this direction probably lies some decades in the future. There is, however, a good prospect that some of the other systems such as the fuel cell, or the thermoelectric or thermionic systems, will become commercially feasible much sooner.

Since nearly all electric distribution and transmission systems are based entirely on the use of alternating current, it will be necessary to provide means for converting the direct-current output of the unconventional systems to alternating current, and to effect such conversion efficiently. Fortunately this problem is far less difficult than those inherent in the unconventional power systems themselves, and it will probably be solved before the new d-c power systems become commercially significant. Indeed, there is ample equipment available today for effecting d-c to a-c conversion. Rotating machinery for doing this has been in use for many years, and Ignitron tube systems using no moving parts are also available for the purpose. This being true, one may ask, where is the problem?

Two-Part Problem

The problem has two parts, one of magnitude, that is, the amount of power to be converted and, the other, voltage. If unconventional power should prove commercially feasible and replace existing generating equipment, the amounts of power that would have to be converted would be enormous. At present, rotating machines are available to handle loads up to 50,000 kw on a single shaft at about $70 per kw. These machines are designed, of course, to operate with conventional d-c power sources, but they can also be designed to operate effectively with the unconventional power systems described in the preceding pages.

However, if such new systems should replace conventional generating equipment, then it would be necessary to convert hundreds of thousands, perhaps even millions, of kilowatts of direct current to alternating current. This poses a difficult but not insurmountable problem. It would be highly desirable to accomplish it by static rather than moving equipment. Commutators on direct-current motors and generators are always a source of trouble in the operation of rotating machines, and at very high power they present formidable problems.

Mercury arc rectifiers, particularly the Ignitron, are well adapted for the conversion of dc to ac, and inverters using such rectifiers have been used for many years. The capacities of these mercury-vapor tube systems are, for all practical purposes, limitless. The cost of these systems de-

FRONTIERS IN POWER RESEARCH

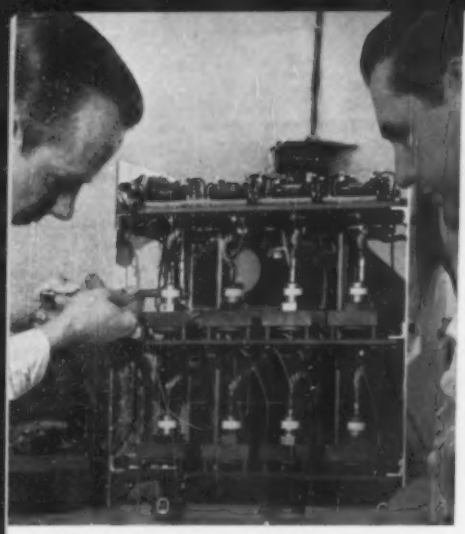
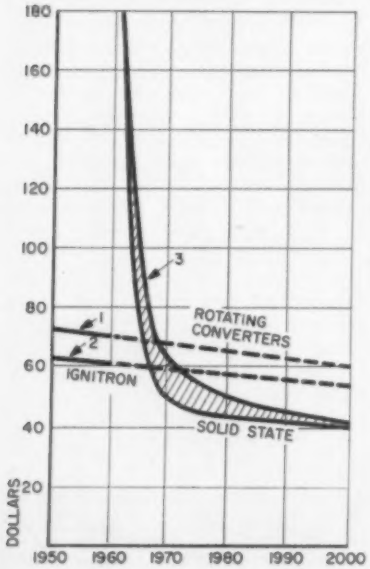


Fig. 1. E. J. Duckett, right, and R. P. Putkovich, Westinghouse engineers, demonstrate operation of a 15-kva solid state power inverter. Eight Trinistor semiconductor switching devices are the basic elements of the system

pends upon the voltages that have to be handled. In the higher voltage range — around 2500 v — the cost of an Ignitron system drops to about $50 per kw. For 600-v application, the cost is higher — approximately $50 per kw. Both the rotating systems and the static Ignitron systems have high conversion efficiencies and are the result of many years of intensive research and development.

Although both the rotating and mercury arc systems have proved feasible, in recent years increasing attention has been given to the development of solid state devices for conversion purposes. This type of research owes its origin to the development of the transistor. At Westinghouse, for example, they have developed a device which they call a Trinistor. This, the basic element in a new static inverter system, is a solid state conductor switch.

Fig. 2. Graph below shows the power conversion equipment costs per kilowatt



Fundamentally, this Trinistor is an element in a circuit that can be controlled to conduct or not to conduct. Using this device, circuits have been developed which alternately open and close in such a way as to take power from a d-c source and produce single phase or three phase a-c power that has the frequency and waveform of the standard distributed ac.

Working with this Trinistor, equipment has been developed for converting ac to dc; dc to dc with a change in the voltage level; and ac to ac with a change in frequency. For the high power region, however, the major portion of the engineering at Westinghouse has been directed toward the conversion of dc to ac. A photograph of a 15-kva inverter using Trinistors, is shown in Fig. 1.

Control by Wafer

Controlling the current within the Trinistor is a tiny silicon wafer, an element smaller than a dime. Today, this particular wafer has the ability to switch 100 amp at 200 v. It is expected that improved materials and techniques will permit it to switch 1000 amp at 1000 v within the next five years. If this prediction comes true, it will place this type of inverter equipment in the 1000-kw range, high enough in power range to serve the first successful unconventional power generating systems.

According to Westinghouse engineers this is no blue-sky forecast because the dramatic leap forward has proved to be standard operating procedure in the development of the new Trinistor power conversion systems. Five years ago, the semiconductor systems at Westinghouse had a top capacity of only 50 watts. In the fall of 1959 the capacity had grown to 10 kw, and in March 1960, power levels in the 150-kw region were being achieved. These systems have the capability of being developed into a series of systems for power in the one to two megawatt range.

As research on the Trinistor type solid state switch and the associated static elements in inversion systems continues, it is predicted that such systems will be able to handle loads from 10 to 100 megawatts by 1965.

Among the advantages of solid state conversion equipment are:

High Efficiency. The present efficiency of conversion with semiconductor devices ranges from 85 to 90 per cent. As the semiconductors and circuitry develop, the efficiency should rise above 90 per cent.

High Reliability, due largely to the absence of moving parts.

Reduced weight and volume. This is another important advantage of solid state power conversion systems.

Also, these systems possess *instant availability* since these static converters bypass the problem of inertia delay, normally present in rotating machines.

And finally, there is the advantage of *ultimately lower cost,* especially in the lower voltage range predicted for most of the new methods of power generation.

On the basis of everything that is known today, Westinghouse predicts the anticipated costs of Trinistor conversion systems to follow the curves shown in Fig. 2. The ordinates on this chart represent the average cost per kilowatt for a complete inversion system, complete in that it produces a-c power with regulated and controllable voltage, regulated frequency, and is capable of supplying reactive power.

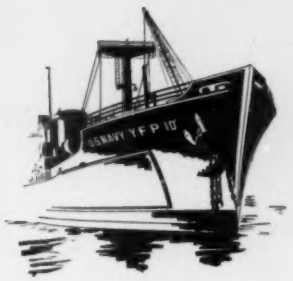
As a basis for comparison, curve 1 represents the cost of a rotating conversion system. Today, this cost is $70 per kw, and it is assumed that improvements in engineering and production techniques will bring the cost down slightly in the future. Curve 2 tells the same story of an Ignitron system in the 600-v range. Here also, future developments should result in a slight cost reduction, going from about $60 per kw to around $55 per kw.

Curve 3 shows the predicted trend for Trinistor systems. Here future costs are predicted in the form of a wide band. The actual costs should lie somewhere around it. Which edge of the band actual costs will come close to will depend largely on the rapidly changing cost picture concerning the semiconductor devices used in the systems. Despite certain unpredictables, those closely involved in the development of these systems are of the opinion that the cost of a complete Trinistor system in the 50 to 100 megawatt power range will come into line with the rotating system cost somewhere around 1965 and 1966. From then on, the cost of the solid state systems will become substantially more economical than both the rotating equipment and the Ignitron systems. THE END

FRONTIERS IN POWER RESEARCH

PACKAGED POWER IN THE FAR NORTH

SECOND HALF OF AN ARTICLE ON AIR FORCE'S FLOATING POWER PLANT IN THE ARCTIC



Editor's Note: *Last month, we gave our readers the first half of the fascinating story on how a power plant was floated up to Thule Air Force Base.*

This article concludes the description of a very ingenious project—one in which power engineers from the Air Force, and Metcalf and Eddy, joined talents to provide a relatively simple solution to a very complicated problem.

BERTHING PROBLEM at Thule was to provide protection from wave action and harbor ice, and to minimize all ship motion caused by winds and tides. This would permit permanent connections to on-base utility systems. We decided on a completely enclosed basin and a modified *spud-mooring* system.

Ship's mooring system limits lateral and transverse movement to a few inches, but still allows vertical movement caused by tide and draft changes and listing caused by windloads and variations in ballast.

Power ship is berthed at the end of a 400-ft rock jetty extending into North Star Bay and is enclosed in a basin constructed of rock fill, with a gravel-fill steel piling dock. One of the prime considerations in selecting this particular berthing site was the quality of sea water in this particular harbor location. Water here is relatively uncontaminated by river silt and base sewage; also sea water is used for condenser service.

Circulation of sea water through the basin is necessary to flush out bilge and sewage wastes from the ship, and to prevent overheating of the basin water in warm weather and extensive ice formation in cold weather. Two openings in the dock provide for this circulation: a discharge port for condenser circulating water, and an intake port aft of the ship to maintain the basin water level.

Condenser circulating water is discharged from the ship through three 24-in. pipes penetrating the hull below the water line. Entrainment of additional water by these submerged jets is such that the actual flow through the basin discharge port is more than double that being pumped. Resultant head differential between the basin and the harbor causes sufficient water flow through the intake port to produce the necessary circulation of water through the basin.

Adequacy of the mooring system was proved this past winter when several violent wind storms were experienced without incident. During extreme cold periods the basin was almost completely covered with a thin layer of ice. In milder winter weather, there was open water in the basin, which steamed, even though its temperature was only 30 F.

Base Steam System

Incorporation of the YFP-10 into the steam and power utility systems of the Thule base required a redesign of the steam distribution and electrical distribution systems. In general, the new arrangement called for provision of steam and electric power to the base buildings by the power ship, to be supplemented when and where necessary by the ten existing heating and power plants.

The ship produces 115,400 pounds per hour of steam, desuperheated to 85 psig and 530 F. Five 8-in. steam lines carry the steam from the export steam header to a 20-in. steam main on the dock, each line being equipped with a system of five Barco ball joints. These joints provide the necessary flexibility to compensate for any movement of the ship. A second desuperheating station on the dock further reduces the temperature of the steam to a range of 350 to 400 F, with the steam retaining some superheat throughout the system. Provision of the second desuperheater station on the dock was made necessary by the design schedule.

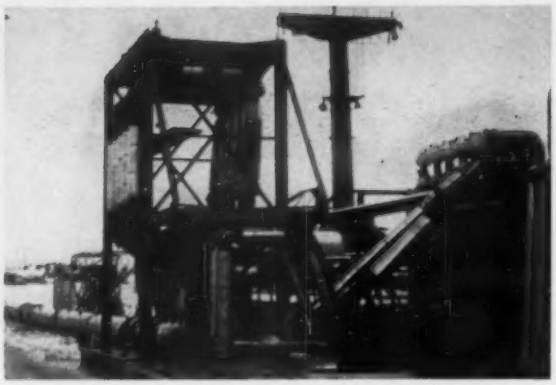
Available information at the outset of design was not sufficiently complete to permit specification of the exact pressure temperature reduction required. When the necessary data were developed, it was found necessary to provide the second desuperheater station.

Delivery of steam throughout the distribution system with a small amount of superheat remaining at the farthest point minimizes the amount of condensate formed in the piping. Maximum temperature of 400 F is necessary to protect the steam coils and building heating equipment at the beginning of the distribution system. A high-temperature alarm installed in the steam main upstream of the desuperheater warns the operator on the ship if the steam temperature rises above the predetermined maximum.

Water for the shore desuperheater station is pumped directly from the condensate return line ahead of the back-pressure valves. Since high-

By summer, the ship is berthed in the completed lagoon as work proceeds on the dock facilities. Icebergs can be seen in the background of the harbor

View along the jetty shows the desuperheater station, substation on shore, and base tank area in the background



View of the overboard piping shows the support tower for export steam mains and ball joints in the individual lines

pressure steam is not available from the ship, a mechanically atomized water spray desuperheater with air-operated control valves is used. This type requires only a high-pressure water pump and an air compressor for operation.

New steam distribution system provides for the supply of steam at a pressure of 70 to 80 psi from the ship, as well as the interchange of steam between the ship and the ten steam heating plants of the base. This permits equalization of steam pressures between the heavier loaded and lighter loaded sections of the system.

Control of the base steam pressure is accomplished in the following manner. An indicating flow meter installed in the main steam header at the desuperheater station on the dock indicates the amount of export steam being furnished by the ship. A transmitter conveys this reading electrically to an indicator on the ship. In addition, indicating pressure gages are installed at three key locations in the steam distribution system. The readings of these gages are electrically transmitted to a central load dispatcher station in the base area.

When the pressure gages show a drop or rise of pressure in any segment of the system, the dispatcher requests the operator in the plant closest to the critical area to fire or shut down a boiler so that a constant pressure may be maintained in the mains. The variance in heating load requirements is normally gradual. A study of the pressure variation in the steam distribution mains indicates that differentials are so slight that automatic control of the heating boiler is not practical.

Cellular glass insulation is used on all outdoor steam, condensate return and water lines. This material is chosen because of its high compressive strength, suitability for high and low temperatures, moisture resistance, and fireproof quality. Metal covering protects the insulation from erosion by wind-driven sand and ice particles. All shore lines are supported by timber sleepers placed on a gravel pad.

Terminations of lines on the ship are supported on frames approximately 10 ft above main deck level. Terminations of lines on the dock are supported on a 21-ft structural steel tower.

Barco ball joints on the steam supply mains, as well as the ball joints on the water and condensate return lines, are protected with block mineral insulation and covered with a windproof bagging material.

Potable water and condensate return lines are heated by mineral-insulated electric heating cables which trace the pipe. These cables are energized automatically so that a minimum temperature of 40 degrees is maintained in the lines.

Electrical Features

Steam turbine generators on the YFP-10 are operated at a terminal voltage of 13,800 volts. Each of the three generators is Y-connected through a circuit breaker and reactor to ground, and is equipped with individual direct-connected exciters. The main 15-kv switchgear comprises a 1200-amp, 500-mva interrupt-rating air circuit breaker for each generator, three outgoing feeders, and two station service feeders. Power is taken from the ship through three sets of three 1250 MCM, 15-kv, single conductor cables, terminating in 15-kv single conductor potheads. Any two of the three feeders can carry the total output of the ship's plant.

Although modifications of the ship's power system were relatively minor, it was necessary to essentially redesign the entire Thule base electrical distribution system, in addition to providing for the transmission of power to the distant BMEWS facility.

Major features of the electrical design, contingent on the use of the ship as a central power source, comprised the following:

1. Design of a key distribution substation which would receive the three 13-kv feeders from the ship and from which would emanate a 69-kv overhead transmission line to the remote BMEWS facility.

2. Two separate 13-kv overhead transmission lines to two additional distribution substations for supplying the base. Feeders from the two base distribution substations are connected by 5-kv feeders to the various central heating and power plants positioned throughout the base.

One of the chief complications in the redesign of the electrical distribution system was the integration of the diesel generator units which formerly were operated as isolated units. The resulting electrical distribution system permits the interchange of electrical power between the central supply from the ship and the twenty-eight 500-kw diesel generators in the plants located throughout the base.

Other electrical design features included the alteration and extension of the existing 4-kv transmission system, made necessary by the proposed interchange of power; the design of a comprehensive protective relaying system for the entire electrical network; and the incorporation of instrumentation essential to the operation and control of the various diesel generators and steam turbine-generators on the ship.

With the YFP-10 in operation, power is now available for one of our nation's all-important ballistic missile detection installations — a radar facility that can probe the skies 3000 miles and provide warning that will permit massive retaliation. THE END

ASME WINTER ANNUAL MEETING LOOKS AT POWER FIELD'S FUTURE

AT THE WINTER annual meeting of the American Society of Mechanical Engineers in New York, Nov 27 to Dec 2, probably the most interesting sessions to power engineers were those devoted to nuclear and "exotic" power sources. In a panel discussion, several authors gave status reports on some of the most prominent nuclear plants in the country. These included the Yankee, Enrico Fermi, Dresden and Indian Point stations.

Other panel discussion was on the subject of direct conversion of heat to electrical energy and included thermionic converters, thermoelectric power generation, fuel cells, and MHD (magnetohydrodynamics).

Also in the field of unusual power sources, sessions were devoted to solar energy. These covered the fields of research and gave progress reports on the present-day applications of solar energy.

On the general side, the Society's top honors were presented to two engineers. Henry T. Heald, president of the Ford Foundation, was made an honorary member of ASME. Professor Carl R. Soderberg was awarded the ASME medal. William H. Byrne was elected ASME president for 1961, succeeding Walker L. Cisler, 1960 president.

At the President's Luncheon, Mr. Cisler gave as the theme of his talk "Whither ASME?" A few direct quotes from it:

"May I say now that *five of our professional divisions are celebrating their fortieth anniversaries* at this time. They are the divisions of Aviation, Fuels, Materials Handling, Power and Railroads . . .

"I have great hope for the study of ASME now being conducted by Cresap, McCormick and Paget, a recognized organization of management advisers having broad experience in the affairs of nonprofit organizations and professional associations, in addition to those engaged in business . . .

"Within the agreed-upon limits of time and budget, they will study our membership, divisions, regions and sections, central staff and voluntary committees, meetings and conventions and publications.

"Out of this study, conducted with the advantage of an outside point of view, will come facts, conclusions and recommendations about ASME that will be most helpful to the Council."

As an adjunct to the meeting, inspection trips were available to the Indian Point Station, Bayonne Research Laboratory of International Nickel Co, New York International Airport, Princeton Stellarator Laboratory and Grumann Aircraft Corporation.

Important feature of some of the sessions on power subjects was that many of the speakers delivered their papers by informal talks, abstracting the most important points of their papers, which were available at the session room, and using only a few of the key lantern slides. This procedure, which has been long advocated, increases audience interest, promotes discussion and is to be highly commended. Also, in two or three of the panel sessions, there was good discussion from the floor.

One of the most interesting of these panel sessions was on Furnace Safeguards, important because of recent explosions or "bumps" in boiler furnaces. The panel and the audience brought out such points as: the effectiveness of ignition burners with the different fuels; necessity for proper procedures in starting and load pick-up and in shutting down; flame detection for individual burners and for complete flame envelope; problems of too-rich fuel mixture; proper instrumentation to tell the operator what he needs to know; problem of training the operator in what to do if computers and automatic controls fail to operate the boiler as desired.

Research and experiments with Magnetohydrodynamic power generation, in amounts up to 10 kw for short periods, were reported by leaders in that field.

Technical details of a new 25,000-kw free-piston power station in Noumea, near Australia, were presented by M. Barthalon. The station contains four gas turbine units, each of 6000 kw capacity. Each unit is supplied with gas by a battery of nine free-piston machines. The sta-

Session of ASME council at 1960 Winter Annual Meeting. At head of table, l to r: William H. Byrne, incoming 1961 president; Walker L. Cisler, 1960 president; and O. B. Schier II, secretary

This is a view of the President's Luncheon of the 1960 Winter Annual Meeting of ASME. Society's outgoing President, Walker L. Cisler, spoke on the topic "Whither ASME?" and outlined areas for future progress of the society

tion supplies power for a large nickel processing plant, in parallel with an existing 4000-kw steam turbine plant and a 76,000-kva hydroelectric plant. Reasons for selection of the free-piston plant, and results after 2000 hr of operation, are given in the paper.

Much interest was shown in papers on various aspects of boiler operation and feedwater treatment. Formation of nitrogen oxides in boiler furnaces under different combustion conditions was explained by J. D. Sensenbaugh and James Jonakin.

W. F. Cantieri and R. E. Chappell reviewed the successful application of slurry-sprayed additives to oil-fired boiler tubes, to combat oil-ash corrosion, for 1 to 5 years, in boilers of Florida Power & Light Co. A slurry of magnesium oxide is sprayed through the soot blowers, under automatic control. Comments on use of dry additives were given, also on thermal shock on tubes, and an outline of future programs was given by the authors.

Combatting oil-ash corrosion by use of new high-chromium high-nickel alloys, as well as oil treatment, additives, protective coatings, and design changes, was discussed by D. W. McDowell, Jr, and J. R. Mihalisin.

Dewpoint Meter Measurements in Boiler Flue Gases, made in 11 American stations, were discussed by A. W. Black, C. F. Stark and W. H. Underwood. This meter is used to estimate the tendency of flue gas to cause deposits and corrosion in air preheaters.

Chemical cleaning of boiler equipment was covered extensively. W. B. Willsey pointed out the benefits of controlling silica and other products originating from the preboiler cycle, by careful cleaning before operation. This would include cleaning of not only the feedwater system but also the steam sides of heaters, bleeder lines, drain lines and the hotwell. The author detailed advantages and methods of doing this. H. J. Vyhnalek gave procedures and precautions for chemical cleaning of controlled-circulation boilers.

Details of chemical cleaning with citric acid and the differences between it and ammoniated citric acid, and their relations to steel and iron oxides, were brought out by W. E. Bell. Precautions to be observed in citric acid cleaning were given by E. B. Morris.

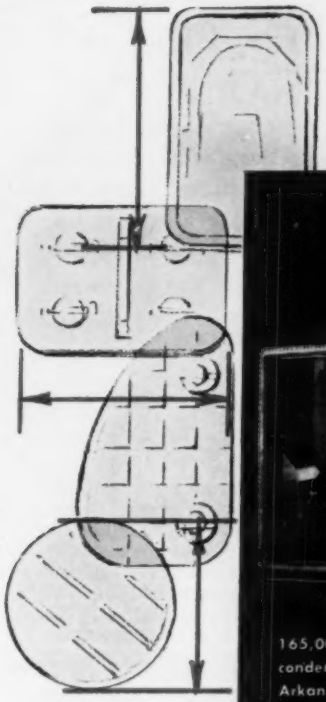
Other papers were: Acid Cleaning of Superheaters and Reheaters, by Ashton and Rose; Effect of Ammonia Injection on Corrosion in Air Preheaters, by Kato and Paris; Relation Between Boiler Cleanliness and Feedwater, by Neat; Methods of Obtaining Accurate Boiler Water Level Indication, by J. W. Williams; Economy of Efficient Air Preheating with Extraction Steam, by M. K. Drewry.

John I. Yellott delivered a progress report on applications of solar energy throughout the world, including its uses for domestic space and water heating, sea water distillation, direct power conversion and solar furnaces in various countries. Progress in Space Heating with Solar Energy, by C. D. Engebretson and N. G. Ashar, described the construction and operation of a solar-heated house in Massachusetts. Also, steam can be generated in a solar-energy steam generator, as described by A. R. Yappel. It would be expensive but might be useful in remote parts of the earth where there is no fuel, or for power generation in space satellites. Heat at 3140 F for a thermionic generator was the objective of a solar concentrator development described by Gillette, Snyder and Timar.

24th National Power Show

Concurrently with the Winter Annual Meeting of ASME, the National Power Show was held in the New York Coliseum, Nov 30 to Dec 2. In this show, 150 manufacturers displayed a wide variety of piping, valves, insulation, automatic controls and instruments, compressors, water treatment equipment, package boilers, and much power plant maintenance equipment. A feature of the Show was a fuel cell, mounted in a suitcase with its bottles of oxygen and hydrogen and controls; it produced power for driving a small electric fan. THE END

View of one floor of 24th National Power Show in the New York Coliseum



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ANY SIZE . . . ANY ARRANGEMENT

165,000 square foot double twin bank surface condenser, designed to a "T", is now installed in Arkansas Power & Light's Helena, Arkansas plant.

Consulting Engineers: Ebasco Services Incorporated

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Yuba's twin-bank tube layout, seen here in a two shell "T" type installation, promotes unobstructed, equally distributed flow. Through Yuba's patented design, the condensate can be deaerated with oxygen content guaranteed to be less than 0.005 cc per liter.

As a design extra, Yuba staggers the tube support plates – reducing harmonics – eliminating vibration. These are some of the reasons why Yuba surface condensers of all sizes have been installed in plants throughout the world. You'll want to know more about the most versatile tube bank layout in the industry – contact Yuba today.

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Power Engineering

HANDBOOK

By **BERT McHENRY,** Engineer Examiner, City of Seattle. Republication rights reserved by the author

Basic Facts About Combustion and Fire Controls

COMBUSTION is the process of burning fuel and air in a given space. This combustion produces hot gases, smoke and soot.

In steam boilers, hot air furnaces, hot water boilers or any other oil-, coal-, wood- or gas-fired furnace, the desired result is to obtain the most heat from the fuel and air mixture with the least losses through smoke, soot, ash and carbon accumulations. Too little air will cause a fire to smoke heavily, creating a large amount of soot. Too little fuel will cause insufficient heating.

Poor combustion wastes fuel. It also causes soot accumulations on the fire heating surfaces, which insulate the metal from the hot gases. This insulation prevents much of the heat from passing through the metal fire and heating surfaces, with the result that heat is wasted.

Oil is sprayed into the firebox, under pressure, through a nozzle which breaks it into a very fine spray. Air is blown past metal fins which cause the air to swirl around and thoroughly mix with the oil. This mixture is then ignited by a pilot light from a gas jet or a pair of electrodes situated so the mixture will ignite quickly without accumulating oil in the firebox. The firebox and combustion chamber in the furnace allow this mixture to burn completely before it passes out through the firetubes and the smoke stack.

Several devices are provided on an automatic oil-fired burner to supply the proper amount of fuel, air, and ignite the fuel mixture. Controls are also provided to assure that the fire is turned on when it should be and to shut it off when it is not needed. Other controls are provided which shut off the burner equipment if the fire does not light as it should.

Typical oil burner installation would include a storage tank, oil lines, an oil filter, oil pump, burner tip or nozzle, an air blower and a motor or motors to operate the oil pump and blower, as well as a number of automatic safety controls.

The storage tank, in which oil is kept for use, can become dirty, rusty, and may allow water to enter the oil. When water mixes with oil, a sludge is formed which can cause blocked oil lines and poorly operating burner equipment. For this reason, the oil supply tank should be checked occasionally by drawing samples from the bottom of the tank.

A filter should be placed in the oil line to the burner to remove water, sludge and dirt or rust from the oil before it gets to the oil pump and burner. This filter should be cleaned frequently, according to instructions. Dirt, rust and sludge passing through the pump and the oil burner nozzle cause undue wear and may occasionally cause a stoppage in the oil feed lines.

The oil pump sucks oil through the oil lines and forces it through the nozzle under pressure. Some oil pumps have oil pressure gages, but most are built without a gage, and the oil pressure remains constant (except when a stoppage occurs).

Small oil filter screens are placed in oil pumps to catch some of the dirt. These should be removed occasionally, cleaned and replaced.

The burner tip or nozzle has a small hole in it and small parts inside which can become restricted or plugged. The burner tip should be wiped off frequently with a rag dipped in solvent or some other cleaning agent and should be taken apart and changed twice a year.

Obtain a spare nozzle of the proper size and have it available for use.

A pilot light igniter is simply a gas jet which is turned on when ignition is required, and is lit by a spark from an electrode. This pilot light then sets fire to the fuel and air mixture. After the fire is burning, the gas jet is automatically turned off.

Manual control of devices used in an automatic oil burner installation would require:

First, the turning on the air blower to purge the firebox of gases; 2. turning on a gas jet; 3. lighting the gas jet; 4. checking to be sure it is burning; 5. turning on an oil pump; 6. being sure the fire is lit; 7. shutting off the gas jet; 8. watching the flame to see that it is burning properly, as evidenced by a bright orange flame, or by hearing the fire burning, or by feeling the heat of the smoke as it passes through the stack; 9. watching the water level, pressure and the heat in the rooms; 10. turning off the burner whenever a dangerous condition occurs or when proper pressure-temperature conditions are evident.

For automatic operation, a number of controls and devices have been provided partially to take the place of the operator in these activities. A master control switch on a fused electrical circuit is provided to turn on the electricity to the various automatic controls. An aquastat, thermostat or pressurestat is provided to turn on the oil burner due to a certain condition. A time cycle control provides the proper sequence for turning on the air blower; the ignition or gas pilot light and the oil pump then turns off the ignition after the fire is lit. A stack switch controlled by change of temperature is provided to shut off the oil burner equipment within a certain time after the fire was supposed to light but failed to do so. This stack switch would also prevent the fire from relighting too soon after the fire had been shut off.

A low water fuel cutout switch connected to a float is provided to turn the burner off in case of low water. A high-pressure cutout switch or pressurestat set at the normal operating pressure of the boiler is provided to turn the burner off when a certain steam pressure is reached.

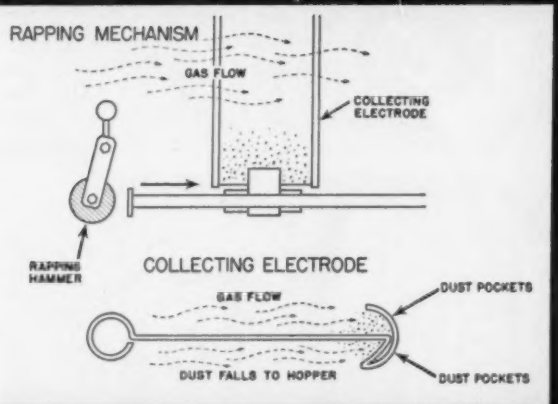
These controls must be checked frequently to see that they are actually performing the function in the system for which they are intended.

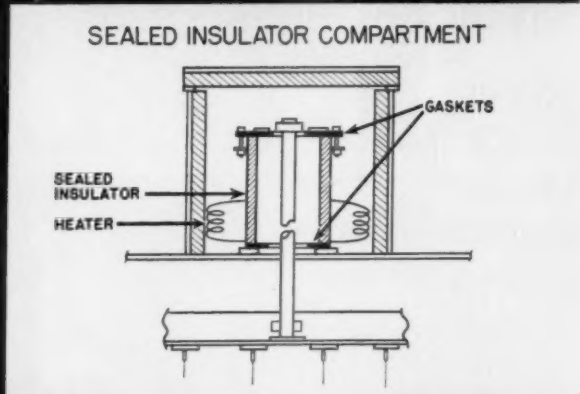
Thermostats and aquastats alone are not safe for operating a steam boiler because the primary concern for safety purposes is steam pressure. Therefore, whenever they are used in steam-boiler operations, the boiler should also have a high-pressure cutout control which would shut the fire off if steam pressure reaches a certain value which would mean danger for the system.

SOME PLAIN FACTS

ABOUT SUPERIOR PRECIPITATOR PERFORMANCE

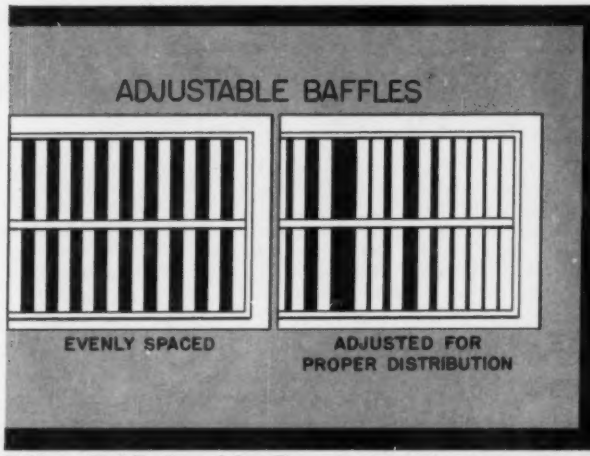
Buell Precipitators are designed and constructed for rugged service and superior performance. Frills and internal frim-fram of a doubtful value are eliminated in favor of strength and simplicity. The casing, outside supports, and internal parts are of rugged construction; and the four-point suspension of emitting electrodes ensures the greatest stability. Here are just a few of the outstanding features of Buell Precipitators.





Effective Continuous Cycle Rapping—Yes, it's mechanical. A simple, rugged system free of complicated gadgets; assures positive dust shearing action. Each row of electrodes is rapped separately—in the direction of the gas flow—on a continuous cycle. Dust is sheared off, drops in an agglomerated mass and pockets on electrodes minimize reentrainment.

Sealed Insulators Improves Operation—High voltage quartz support insulators are completely sealed; prevents gas and dust leaking into insulator compartment and outside air leaking into precipitator. There is no need for costly ventilating systems. Thermostatically controlled electric heaters insure start-up without danger of moisture condensation and insulator breakdown.



Uniform Distribution of Gas Flow—Field adjustment capability is vital. Buell's adjustable baffle permits final positioning after field measurement of actual flow distribution . . . because gas flow patterns are not entirely predictable. The Buell distribution system assures equal gas loading through the precipitator; eliminates ineffective "dead" areas around passages and prevents "sneak-by."

Buell Spiralectrodes cut maintenance to a minimum. Buell's record stands at less than 1% replacement in this key area. Self-tensioned spiralectrodes eliminate vibration and "off-center" swaying, often prevalent with weight-tensioned wires. They're structurally fixed and once installed stay in alignment. The spiralectrode provides greater emission than straight wires.

Buell precipitators are simple and effective. They're designed fo continuous service. You'll be glad you turned to Buell when you experience superior performance and low maintenance. Detailed literature describing all features is available.

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The Buell Engineering Co., Inc., Dept. 52-A, 123 William Street, New York 38, N. Y. Northern Blower Division, 6434 Barberton Avenue., Cleveland, Ohio. ■Electric Precipitators ■Cyclones ■Bag Collectors ■Combination Systems ■Fans ■Classifiers.

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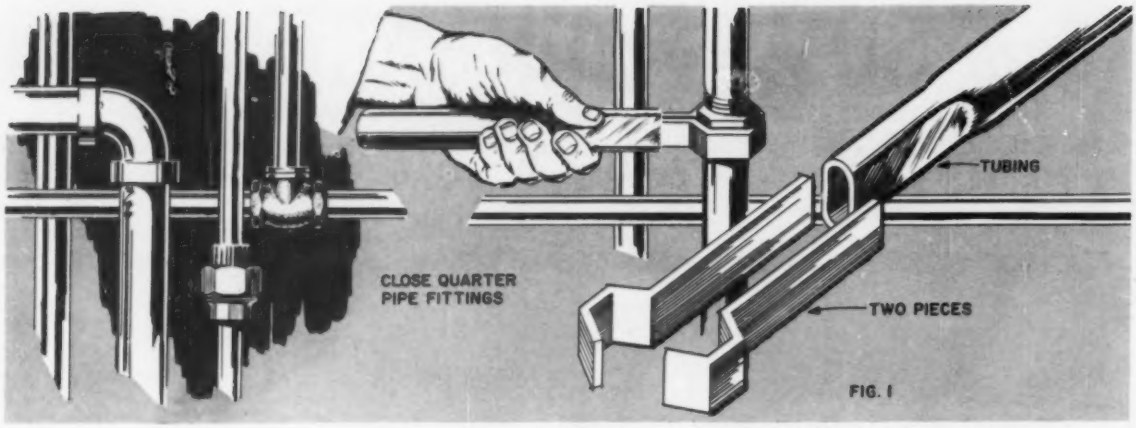

FIG. 1

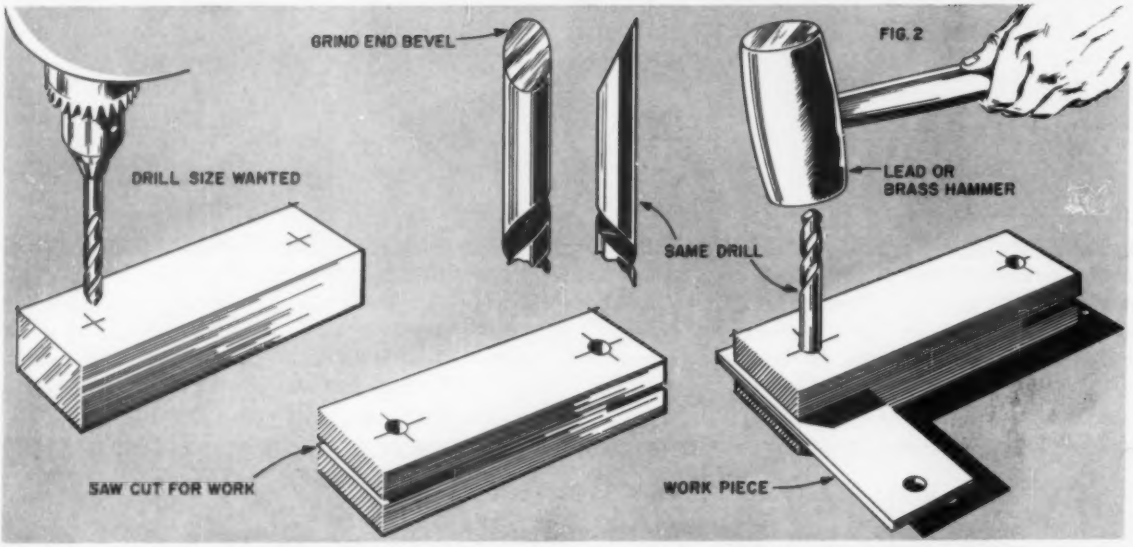

FIG. 2

How to Make a Tight-Corner Wrench and a Small Hole Punch and Die

By CHARLES H. WILLEY

THERE ARE TIMES when the wrench shown in Fig. 1 will save you a lot of bother and time.

For instance, piping is often installed in close quarters, as shown, and arranged so that only special tools can be used to break a union, for example. For such a problem, a straddle box wrench, as shown, is really a necessity.

This tool is made from two flat pieces of steel formed as illustrated. These are placed on the nut, and the tube handle is then placed on them, and you have a wrench that can't slip. Lifting it on and off to change positions allows it to have six point positions.

Figure 2 shows how to make a small hole punch and die useful for such jobs as punching a hole in a clock spring, or thin sheet stock, fiber, brass, etc. Just drill a hole through a piece of steel, saw a cut in the end, and take the drill and grind the shank end on a bevel. Use it as shown, for a punch, using a brass or lead hammer. Strike a sharp, impact blow and you will have a clean, true hole the size you want.

If you don't want to use a drill, a temporary punch can be made of a drill rod or cold rolled steel, with square point, or angled.

Tape Helps In Fitting Brushes

DOUBLE-COATED cellophane tape can be used as an aid in holding abrasive paper to commutators when fitting electrical contact brushes, suggests the Bureau of Ship's *Journal*.

One of the methods commonly used to fit the brushes consists of lifting the brushes, wrapping the commutator with flint or aluminum oxide (production) paper, lowering the brushes, and rotating the commutator by hand until the proper fit is obtained.

The paper has a tendency to slip because the smooth side of the paper makes contact with the commutator. To overcome this difficulty, the stocking of an abrasive paper with adhesive on the opposite side has been suggested; but this would involve procurement of special paper not available commercially.

A solution is to use double-coated cellophane tape such as the number 665 or 400 manufactured by the Minnesota Mining and Manufacturing Co, St. Paul, Minn. This tape can be applied directly to the commutator, and the abrasive paper, when placed over it, will adhere firmly in place on the commutator.

Care must be taken, however, to remove all pieces of the adhesive after the brushes are fitted.

Power Engineering HANDBOOK

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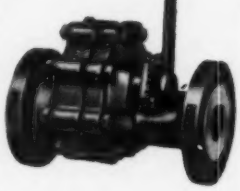

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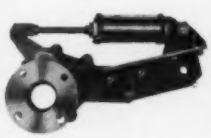

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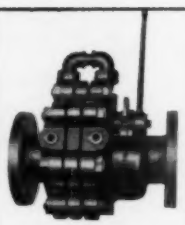

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CONSTRUCTION NEWS

Fayetteville, Ark. — Ozark Rural Electric Corp, 17 North Black St, this city, has authorized plans and work will begin soon under company's own forces on the expansion and installation of rural electric distribution lines in Ozark's service area. Plans also include a short line extension through Washington County and vicinity to expand company's service area. Work will cost $975,000.

Eureka, Calif. — Pacific Gas & Electric Co, 245 Market St, San Francisco, Calif., has announced that it has received a construction permit from the Atomic Energy Commission, Washington, D. C., for the construction of a $19,500,000 nuclear power plant near here. New installation, producing 60,000 kw, will be the third unit in company's Humboldt Bay Plant, which now has two conventional steam-electric plants generating 100,000 kw. Work will begin when preliminary engineering work is completed; work is scheduled for completion by March 1962. Work will be done under the supervision of the Bechtel Corp, of San Francisco, Calif. General Electric Co, Schenectady, N. Y., will supply the nuclear power equipment.

Grass Valley, Calif. — Nevada Irrigation District, Grass Valley, Calif., has requested the Federal Power Commission to grant a license for the construction of a huge hydroelectric project to be built on the Yuba and Bear Rivers in Sierra, Placer, and Nevada Counties of California. The development of the new plant would include two powerhouses with a combined capacity of 59,100 kw, and eight storage reservoirs. Cost of the proposed facility was estimated at $36,800,000 when completed. The power generated would be sold to the Pacific Gas & Electric Co, of San Francisco, Calif.

San Luis Obispo, Calif. — Pacific Gas & Electric Co, 245 Market St, San Francisco, Calif., has announced plans for a major expansion of its Morro Bay Power Plant located here. Plans call for the installation of increased generating capacity to boost the over-all generating capacity to 990,000 kilowatts from the present 330,000. Company has authorized plans for the installation of two new generating units, each with a capacity of 330,000 kw, making the facility the largest steam-electric generating plant in the country. Both installations will represent an investment in excess of $80,000,000.

Jacksonville, Fla. — Municipal Department of Light & Power, City Hall, Jacksonville, Fla., has announced plans for the extension of its Talleyrand Electric Generating Station with installation of equipment for increased capacity. Work will include expansion and modernization of Sections A and B of the plant and will start at once. Company has awarded contract for the work to Johnson, Drake & Piper, Cleveland Consolidated & Cleveland Electric Co, P. O. Box 5097, this city. Cost of the improvement and expansion program will be about $2,472,800.

Riviera Beach, Fla. — Florida Power & Light Co, 25 S. Second St, Miami, Fla., has announced construction which is already under way on the expansion of its Riviera Beach power plant located here. Plans call for the installation of two new generating units, first of which will raise total generating capacity from 140,000 kw to 440,000 kw, scheduled for completion in the summer of 1962; and the second unit, scheduled for completion in 1963, will add another 300,000 kw. Total power generating capacity of the state totals 3,847,000 kilowatts, which is almost four times the total capacity in 1950. Increase in industrial activity has been a primary reason for the added power capacity which represents a multi-million dollar expansion.

Salix, Iowa — Iowa Public Service Co, 502 Sixth St, Sioux City, Iowa, has authorized plans for the construction of a thermal power plant which will include the installation of a turbine-generator and high-pressure boilers, with auxiliary equipment, on a new plant site recently acquired near here. Company has awarded contract in the amount of $2,360,000 to Ebasco Services, Inc, 2 Rector St, New York, N. Y., for design and construction of the new facility. Work is expected to begin at once for completion scheduled for the fourth quarter of 1962.

Burnside, Ky. — East Kentucky Rural Electric Coöperative, Winchester, Ky., is considering plans for the construction of a new steam-electric generating installation near here where large site has been selected. Company has recently secured a loan for the work in the amount of $25,000,000 from the Rural Electrification Administration. Approximately $17,000,000 will go for construction of the Burnside plant, with installation of a steam-electric turbine, having an initial capacity of 100,000 kw, and auxiliary equipment. The balance of approximately $8,000,000 will be used for construction of 342 miles of transmission lines and six additional substations.

Manchester, N. H. — Public Service Co of New Hampshire, 1087 Elm St, this city, has announced plans for expansion of its generating and distribution facilities and has awarded a bond issue of $5,000,000 to repay short-term construction loans and to cover the proposed expansion. Work will include installation of equipment for increased capacity, installation of substations, and distribution lines. Work on the program is already under way and is scheduled for completion in the fall of 1962.

High Point, N. C. — City Department of Light & Power, City Hall, this city, has authorized plans for the expansion and improvement in municipal electric distribution lines for a newly annexed area on the outskirts of this community. Plans call for the installation of new substation facilities, additional new distribution lines, and expansion and improvement of other company equipment. Work on the expansion program has already begun and is scheduled for completion late in 1961 at a cost approximating $2,200,000. L. E. Wooten & Co., Raleigh, are project engineers.

Conesville, O. — Columbus & Southern Ohio Electric Co, 215 North Front St, Columbus, O., has announced plans for a major expansion of its Conesville Generating Station, located here, with the installation of a third steam-electric generating unit for increased capacity. Work will get under way at once under the supervision of Eisenman-Elliot, 37 N. Sylvan Ave, Columbus, O., who are the general contractors. Total cost of the installation will run approximately $20,000,000 when completed in 1962. Westinghouse Electric Corp, Pittsburgh, Pa., will furnish the steam-electric generating unit.

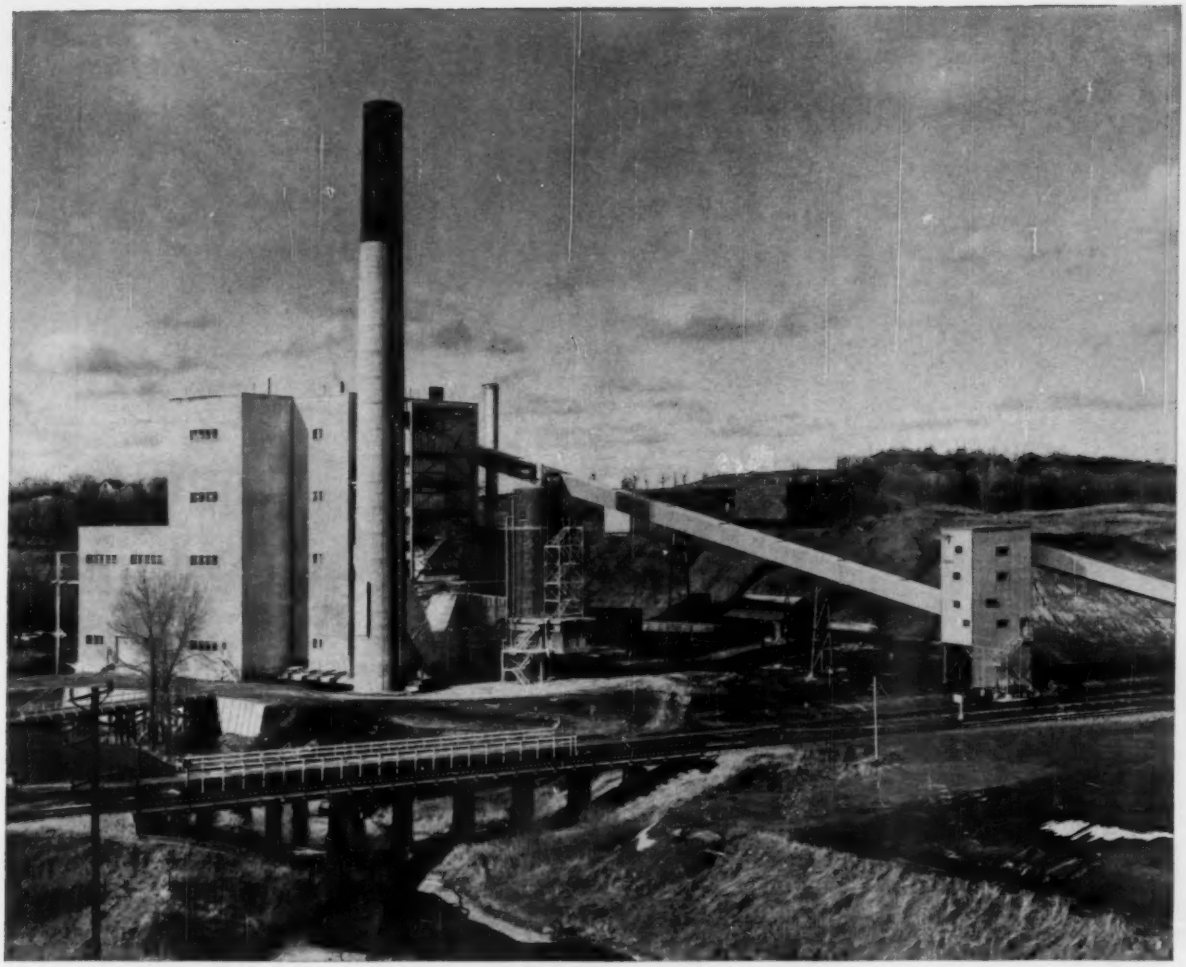
Oklahoma City, Okla. — Oklahoma Gas & Electric Co, 321 North Harvey St, has authorized plans for the expenditure of approximately $13,000,000 for plant expansion and increase to its distribution system in 1961. Company spent a like amount in 1960, the lowest since 1953. Company now has on order a 240,000-kw steam-electric generating turbine which will bring the utility's system capability to 1,234,000 kilowatts when put into service by mid-summer of 1963. Company has announced that although gross revenues had increased through 1960 by 7 per cent, the net income would be about the same as 1959. Earnings rise during a period of large construction outlays and decline when construction is low.

Portland, Ore. — Pacific Power & Light Company, Public Service Bldg, this city, has completed agreements with the Southern Wyoming Utilities Co, of Rock Springs, Wyoming, for the cash purchase of electric and water service systems in Wyoming at a price reported to be $3,200,000. Southern Wyoming Utilities is a wholly-owned subsidiary of Union Pacific Railroad. Purchase includes a 20,000-kw steam-electric generating plant from Union Pacific Coal Co, another subsidiary of the railroad. Transaction will be completed in about 60 days after approval by the Wyoming Public Service Commission, possibly by the early part of 1961.

Courtney, Pa. — West Penn Power Company, Cabin Hill, Greensburg, Pa., has plans under consideration for the construction of a new steam-electric generating addition to company plant located here. Plans include the installation of a 250,000-kw turbine-generator unit, which will get under way in the early part of 1961. Addition to Mitchell Station power plant, which will cost an estimated $3,4000,000 before completion, is scheduled for completion early in 1963. West Penn Power Co is headquartered in Pittsburgh, Pa., and furnishes power and electricity to communities in the Pittsburgh area.

San Angelo, Texas — West Texas Utilities Co, 1062 North Third St, Abilene, Texas, has authorized plans for the construction of a new power plant on a large site here recently acquired for the purpose. Plans call for the installation of a steam-electric generating unit with an initial capacity of 75,000 kw on the site, which, when completed, will be known as the Lake Nasworthy Electric Power Plant. When completed in 1962, the plant will represent an investment of about $9,000,000.

Washington, D. C. — Washington Gas Light Company, 1100 H Street, N. W., this city, has authorized plans and has work already under way on the installation of a 15.8-mile distribution line from Hybia Valley, near Alexandria, Va., across the Potomac River into Prince Georges County, Md. Company will convert 5.36-mile distribution line to a transmission line.



Rated at 53,500 kw, Hoot Lake is Otter Tail's newest station. The Otter Tail Power Company serves a 70,000 square mile area in Minnesota, North and South Dakota. Burns and Roe were consulting engineers.

MINNESOTA UNIT FIRES "WET" COAL

. . . Hoot Lake Station burns 1,000 tons of N.D. lignite daily

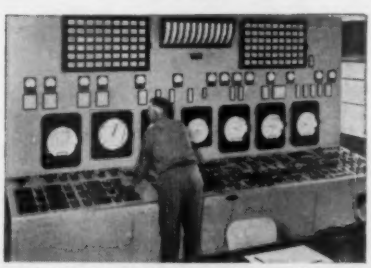
The Otter Tail Power Company's Hoot Lake Station at Fergus Falls, Minnesota, is the largest generating plant in the country burning North Dakota pulverized lignite. The steam generator is the first reheat unit to use lignite as the primary fuel.

Although lignite has a lower initial cost, its high moisture content (30-35%) and low heating value present unusual control problems.

After a year's operation, management is very satisfied with Hagan performance, particularly during several unscheduled outages, when the controls remained on automatic with excellent results. Hagan systems on the unit include combustion, 3-element drum-level, feed-pump, deaerating heater, forced, and induced draft fan control systems.

"Reasons for the selection of Hagan controls," one company official noted, "include satisfactory performance at our other stations, plus the high level of service and instruction provided by Hagan's Regional Service Engineer. We are pleased to have this same proficiency at our Hoot Lake Station."

Look to Hagan for sensible, workmanlike solutions to either special control problems or standard installations. A letter or phone call will put a Hagan engineer to work on your particular problem.



Control Panel at Hoot Lake. Hagan Ring Balance meters and the compact operating console make it easy for a single operator to maintain close control of the operation.

HAGAN
CHEMICALS & CONTROLS, INC.
HAGAN CENTER, PITTSBURGH 30, PA.

HAGAN DIVISIONS: CALGON CO. • HALL LABORATORIES • BRUNER CORP.

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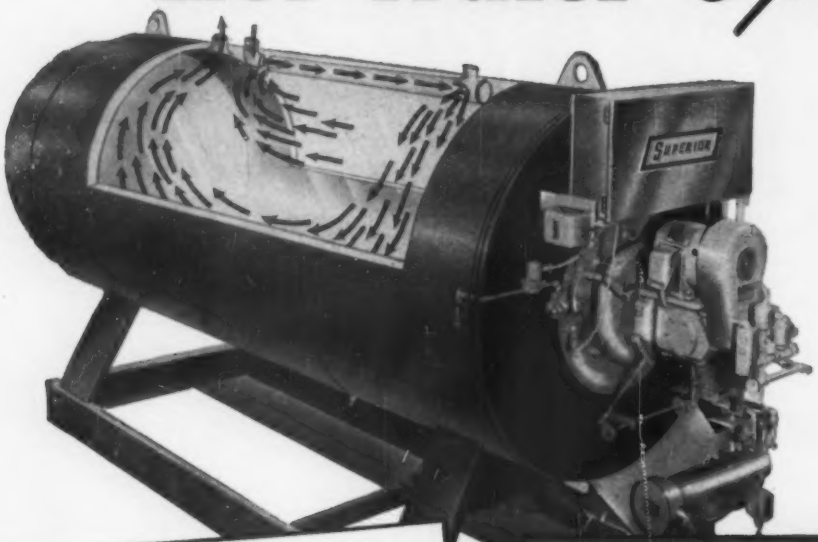
Designed specifically for **Hot Water** *Operation*



with...

Venturi-Action Mixing-Tube

Venturi-Action Mixing Tube
plays a triple role:

1 It starts by mixing entrained water from the boiler with water entering the boiler.

2 Traveling through the tube, temperature is further modified by the surrounding water.

3 Jet action at the end of the tube directs flow downward and outward against the outer confines of the shell, providing a circulation pattern unequalled in any other hot water boiler.

SUPERIOR "TYPE CC"

This new Superior Hot Water Boiler eliminates the problems resulting from the use of steam boilers for hot-water heating. Most of these stem from improper circulation within the boiler.

Its newly designed Venturi-Action Mixing-Tube achieves a more effective use of the natural flow pattern for maximum efficiency in hot water heating.

In addition to its special hot-water design, features include 4-pass down-draft design, 5 sq. ft. of heating surface per bhp., built-in induced draft, fully automatic operation firing gas, oil or both, and a host of other features described in detail in the new catalog illustrated at left.

For sizes to 11,720,000 Btu's/hr., write for catalog CCW-12.
For sizes to 20,100,000 Btu's/hr., write for catalog CFW-12.

Fire-Tube and Water-Tube PACKAGED BOILERS
for STEAM or HOT WATER

SUPERIOR COMBUSTION INDUSTRIES INC.
TIMES TOWER, TIMES SQUARE, NEW YORK 36, N. Y.

SUPERIOR PACKAGED BOILERS ®

For more data circle 529 on Post Card

Current Catalogs

continued from page 32

manual rotary soot blower for use with air, saturated or superheated steam, slurries, or water. External and sectional views of the blowers are included.

153 Electric Soot Blowers — Features and advantages of Copes-Vulcan Div., Blaw-Knox Co. electric rotary soot blowers are detailed in Bulletin 1072. Includes external and sectional views showing details of design and operation.

154 Air-Powered Blowers — Bulletin 1067 describes air-powered rotary soot blowers made by Copes-Vulcan Div., Blaw-Knox Co. Includes external and sectional views of the soot blowers, as well as diagrams showing method of removing soot blower head and element from boiler.

Hose

155 Industrial Hose — Detailed information on Swan Rubber Co.'s industrial hose line is presented in this ring-bound notebook which is designed to accommodate future revisions of the catalog. Covers air hose, water hose, polypurpose hose, welding hose, paint spray hose, booster hose, and others.

156 Hose Style Guide — Twelve-pp Bulletin 627 issued by Aeroquip Corp. serves as a guide for proper hose selection for all types of industrial applications. Listed are 112 separate liquids and gases from acetate solvents to zinc salt solutions — and the suitability of various tubestocks for carrying these agents is charted as excellent, good, conditional, unsatisfactory.

Other Equipment

157 Centrifugal Fans — Small direct-connected, belted and portable centrifugal fans are featured by Ilg Electric Ventilating Co. in 8-pp Bulletin DB2-306. Includes detailed specifications.

When using the Reader Service Cards, please be sure to give your company name and job title, even if you want catalogs sent to your home. Manufacturers prefer to send literature to those who identify themselves

158 Signaling Equipment — Detailed data on signaling equipment — including product descriptions, illustrations, specifications and ordering data — is presented by Edwards Co., Inc., in 38-pp Bulletin S-100 OEM. Covers annunciators, bells and buzzers, chimes, fire alarm equipment, push buttons, and transformers.

159 Cooling Tower Deterioration — Causes, symptoms and suggested cures for deterioration of wood in cooling towers are described in Nalco Chemical Co.'s Reprint 85, 8 pp. Covers principal types of deterioration in wood towers — leaching, delignification, and microbiological attack — and tells how they can be discovered by inspection and checked.

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160 Weight Tables — This 16-pp bulletin issued by Jones & Laughlin Steel Corp. contains tables for computing weight of welded steel tubing. Gives dimensions and weight per foot for round mechanical tubing to 10 in., square and rectangular tubing to 5 in., and pressure tubing to 5 in.

161 Sound Control — Facts on air distribution levels are discussed in Barber-Colman Co.'s Bulletin F-10180, 8 pp. Covers all the factors to consider in planning a comfortable auditory environment.

162 Lighting Lease Plan — Benefits of leasing lighting are explained in Westinghouse Electric Corp.'s Booklet SA-8865. Tells how the plan operates and presents a guide for determining payments.

163 Corrosion Data Charts — Corrosive effects of almost 400 different materials on 16 types of metals are shown in corrosion data charts contained in Technical Service Bulletin 101 issued by Nooter Corp. Charts indicate corrosion resistance of metals to various concentrations of chemical salts and acids, as well as common materials such as water, glue, fruit juices, salt, turpentine, others.

164 Plant Protection — This 30-pp pocket-sized handbook of Detex Watchclock Corp. on property protection covers all aspects of guard selection, training and procedure, uniforms and equipment, the guard's route, etc. Safety and fire checking, first aid, intruders, Sprinkler systems and report writing also are covered.

165 Algebraic Compiler — This 32-pp manual issued by Bendix Corp. describes the language of ALGO, an algebraic compiler for company's general purpose computer. Sets forth the procedures for the representation of numerical data and control statements. Step-by-step examples illustrate principles and operational characteristics of the compiler.

166 The Dresden Story — Twelve-pp Bulletin GED-4275 tells the story of how this country's largest nuclear power plant was built on schedule and within budget by General Electric Co. Included are sections on results of start-up test program, and on the future of large nuclear power generating stations, along with charts and photos of Dresden Station.

167 Air and Electric Tools — Drilling, fastening, abrasive, and special tools (such as saws and routers), as well as electric tools and accessories are featured in 72-pp Catalog 61 offered by Buckeye Tools Corp. Complete selection details and specifications are included.

168 Air Conditioning Units — Detailed information on a packaged central station air conditioning unit designed by American Air Filter Co., Inc. to give exact type and degree of air cleaning is presented in 60-pp Bulletin AC-100. Component features are illustrated, and selection data including psychrometric calculations, size selection, arrangement and location, air volume and velocity data, air resistance, data and engineering specifications given.

169 Liquid Chiller — Hermetic packaged liquid chillers made by American-Standard Industrial Div. are described in 10-pp Bulletin 3926. Illustrates and describes standard mechanical and electrical features and includes tabulation of net rated capacity along with charted cooler and condenser pressure drops.

How to Evaluate Cottrell Precipitators

How important is Precipitator Size?

A common fallacy assumes a larger precipitator with lower gas velocity is preferable to a smaller precipitator with higher gas velocity.

This assumption overlooks important economies now obtained with:

(a) Efficient voltage application

(b) Specific control of electrical sections

(c) Electrode design improvements

(d) Automatic Rapper Control

(e) Accurate internal baffling

(f) Proper control of gas flow, based on three-dimensional model studies

Close familiarity with these techniques and improvements has enabled us to guarantee 99% collection on large, modern installations.

Applied Voltage

Let's take Applied Voltage as a start. *If you double the operating voltage in a precipitator, it is equivalent to adding three times again as much collecting electrode area—or building a precipitator four times as big.*

If Applied Voltage is this important, how can evaluation engineers make sure a precipitator is operating with maximum voltage at all times?

Generally, the amount of arc-over in the precipitator determines the practical operating limit. Provision should be made in the precipitator's control to measure and integrate this arc-over so it can be used as the motivating factor in the control.

Stated simply, a precipitator must have control equipment which guarantees maximum voltage input regardless of changes in gas flow, particle size or resistivity, etc.

Sectionalization

Another important point in evaluating Applied Voltage is the question of how much sectionalization is provided in the specifications. Gas conditions are not constant throughout any precipitator. Higher efficiencies are obtained if the precipitator is divided into sections, each of which has its own voltage control set. In this way, maximum voltage is applied to each section regardless of variations in gas conditions from one section to another.

Reentrainment

Another factor affecting collection efficiency is the possibility of dust reentrainment. This refers to re-suspension of dust that has already been collected on the collecting electrodes.

Engineers are now demanding proof that collecting plate design provides correct baffling to shield the collecting surface against the sweeping and scouring effects of moving gas streams.

Precipitators using properly designed collecting electrodes can be 25% to 50% smaller than a precipitator using improperly designed electrodes. Once again, the emphasis is on proper design, not precipitator "size".

Proper Rapping

Another cause of reentrainment is improper rapping. A rapping blow that is too hard may dislodge too much collected dust and cause reentrainment. On the other hand, if the blow is too "soft", the dust builds up on the collecting electrodes, disrupts electrical conditions and necessitates reduced operating voltage.

As we said, conditions inside the precipitator are not constant. Gas flow, temperature particle size and resistivity are all constantly changing. Rapping intensity must also change to meet these varying conditions. This means that an evaluation engineer must be sure the rapping equipment specified is fully adjustable to meet all these changing conditions.

Sneakage

Now that collection efficiencies demanded by industry are becoming higher and higher, sneakage is an important consideration. This refers to that part of the gas stream which might sneak around the treatment zone.

Proper internal baffling is the only way to make sure that the entire gas stream flows through the treatment zone. For this, evaluation engineers must rely on the experience of the precipitator manufacturer in three dimensional model studies and research on full-scale precipitators.

Gas Flow Pattern

A major factor affecting the relationship between precipitator size and performance is the gas flow pattern across the face of the precipitator. When you consider the fact that proper flow can mean another 25% - 50% reduction in precipitator size, it pays to investigate the design elements affecting this gas flow pattern. Again, evaluation engineers should ask the manufacturer how he has provided for correct gas flow.

In this brief review we have been able to hit only a few high spots of precipitator evaluation. It is a complicated problem because of the many variables in gas conditions and the combinations of electrical, electronic and mechanical equipment involved.

If you want more information on any of the points discussed in this review, please contact your nearest Research-Cottrell representative or write us in Bound Brook, N. J. Our 48 years of gas cleaning experience are at your service.

Research-Cottrell, Inc.
Office and Plant: Bound Brook, N. J.
Representatives in principal cities of U.S. and Canada

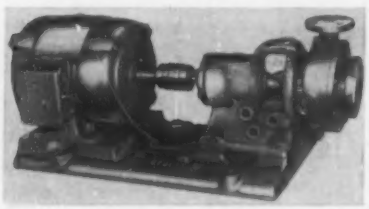
For more data circle 527 on Post Card

Equipment News

Described on these pages are new and improved products. Use Reader Service Cards on pages 85–86 to ask for more information on them. Just circle the item numbers of all the products in which you are interested.

1—Instrument provides continuous on-stream water analysis

Introduced by Hagan Chemicals & Controls, Inc., the Chemonitor duplicates continuously and automatically the principles of colorimetric analysis, thus determining and recording the amount of a specific component in water. A sample is piped into instrument and mixed



with reagents. When silica is present, the sample turns blue. Intensity of color is then measured by the colorimeter and the measurement recorded on a recorder. When desired, the recorder operates an upper-limit switch which, in turn, actuates an alarm system. In the zero to 300 ppb silicon range, the Chemonitor permits detection of concentrations as low as 5 ppb with ± 2 ppb accuracy. Typical applications are analysis of boiled water, condensate and effluents from demineralizers, water softeners, and waste disposal treatment plants. The Chemonitor can be set up to conduct single or multiple point analysis.

2—Fast flow rate filter aid for viscous materials

Celite 560 is announced by Johns-Manville as a diatomite filter aid having a flow rate nearly double that of previous materials. It is claimed to enable filtration of extremely viscous materials that could not previously be filtered with filter aids because of low permeability.

4—Tray deaerators give maximum corrosion protection

These tray deaerators are designed by The Permutit Co. to protect against corrosion of boiler tubes, internals, feedwater lines, auxiliaries and condensate return lines by removing non-condensable corrosive gases from boiler feedwater. According to company, effective deaeration of boiler feedwater is guaranteed to specified low quantities of gases (0.005 ml oxygen per liter of water and zero CO_2), regardless of variations in load or amount of gases initially present.

5—Multi-purpose lubricant comes in cartridge form

For use in any lever-type gun made for cartridge grease, No. 88X Light is described by Keystone Lubricating Co. as water repellant, unaffected by heat or cold and resistant to mild acids and alkalis. Company says it is especially suitable for plain and anti-friction bearings and for application on rotating or sliding surfaces. Cartridges install quickly.

6—Diaphragm relief valve for corrosive services

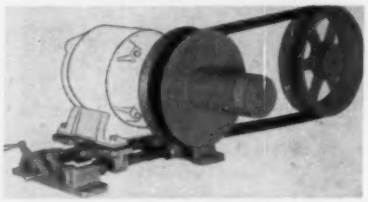
Designed by Farris Engineering Corp. for service where corrosive chemicals are a problem, Series 1000 Diaphragm Relief Valve provides a vapor tight seal to prevent leakage and eliminate waste. Spring and guides are isolated from process fluid to avoid corrosion. Valve is especially suited for nitrogen and other light gas service where tight valve is required, company says, and for water treatment applications where acids and alkalis in concentrated form are used. It comes in steel, bronze and Hastelloy C for body, with Neoprene, Molded Kel-F or stainless diaphragm and disc, sizes ½ through 2 in.

7—Position indicator detects fluid level, mechanical motion

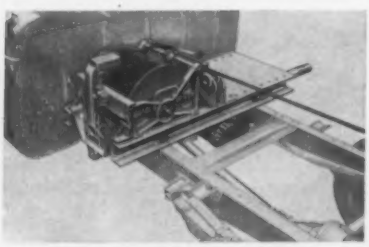
Compact and simple, this development of The Gems Co., Inc., is announced as providing a continuous meter reading up to 10 ft of mechanical travel or fluid level. High and low contacts may be incorporated within the probe to operate remotely located warning lights or other type of indicator. Contact meters are available for any mid-range, adjustable signals. In the basic unit, a traveler or float rides along a probe connected to a direct reading receiver — mounted remotely or directly to the probe. A follower within the probe, and magnetically coupled with the moving traveler, shunts out part of a resistive circuit, across which receiver meter is connected, on Wheatstone bridge principle.

8—Variable speed drive has a 3-to-1 speed ratio

Used with adjustable motor base, one variable speed belt and a companion V-groove sheave, the 1325 Roto Cone converts any constant speed motor or other



driving power source, to a variable speed drive that delivers infinite speed control within the range while machine is in operation, according to Gerbing Mfg. Corp. Rated 25 hp, 1750 rpm, with 3-to-1 speed change ratio, it has a rack and gear arrangement designed to give positive and equal linear movement to each pulley disc. Movement of one disc is opposite to that of other, causing belt to travel on a fixed center line throughout speed range. Catalog 660 gives details.



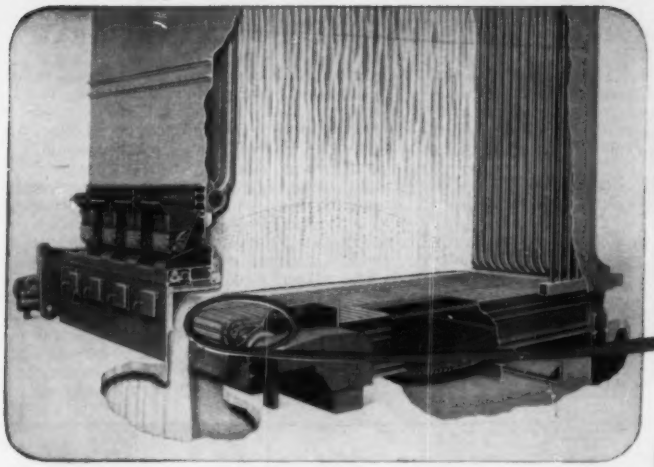
3—Hydraulic winch offers improved cable handling

Model CL (for constant load) is a hydraulic winch designed to combine constant load, speed and horsepower with safe one-man operation. It is a development of Braden Winch Div., Motor Products Corp. Basis for this cable-handling system is separation of power and storage functions of the winch, usually combined in a single drum. In the Model CL, two power drums do the pulling while a large capacity storage drum takes up the cable. Manufacturer explains that speed and load remain constant throughout operation because there is no build-up of layers of cable on the drums. At the same time, an improved level winder protects winch cable and load by even winding on the storage drum.

Safety is achieved with an automatic worm brake, self-adjusting to wear and load. The load on the cable applies the brake pressure. In the event of a power loss, the brake is designed to lock automatically, holding the load until power is restored. One-man operation is made possible by the winch's remote control system with only two control levers: one operates the hydraulic valve; the other operates the three-speed winch transmission. The basic model handles ⅛- or 7/16-in. diam cable, and the drum holds 1000 ft of ½-in. cable. It has a 15,000-lb rating, but is claimed to out-perform a conventional 20,000-lb winch by pulling an equal load much farther without overheating. It is operated by a relatively small pump and motor.

9—High speed automatic monitor does its trouble-shooting

An ultra reliable 120-point high-speed automatic monitor system with scanning rate up to 5000 inputs a second (200 microseconds per point) and self-checking features is announced by Monitor Systems, Inc. This solid state system measures temperatures in voltage form and rate of change of temperatures, compares both to preset values, and converts to digital form for readout in binary decimal code and cathode ray tube display. In addition, the system monitors irrational high and low temperatures and approach-to-trip. Scanning rate is adjustable to 5 kc, 2.5 kc, 0.5 kc or manual. There are five types of alarm conditions: temperature; rate of change; approach-to-trip; irrational



Long grate bars with closely fitting overlay joints prevent leakages. Venturi air openings are spaced to provide uniform air distribution.

GRATES ARE THE GUTS OF A STOKER — DETROIT ROTOGRATE HAS PLENTY OF INTESTINAL FORTITUDE

No matter what else it has, no stoker can be a complete success without trouble free efficient grates.

The Detroit RotoGrate Stoker has other outstanding features in abundance but without the superior grate design it could never have achieved such instant and lasting success.

The advent of the RotoGrate Stoker established a whole new trend in coal firing and stimulated many competitors but none has seriously challenged the superior performance and long life of the RotoGrate.

Our grates are high resistance metering type with venturi air openings spaced to provide uniform air distribution. Long grate bars have close fitting overlay joints to prevent leakages that cause blow holes and burnouts.

Sturdy construction and use of special alloy iron makes these grates long lasting under the most exacting service.

Guide chains riding over toothed sprockets assure positive grate bar alignment. A unique method of attachment avoids chain wear and stretching, while the catenary take up of slack prevents jamming.

Forward travel continuously discharges ash. Automatic combustion control varies the speed of travel in step with fuel feed rate to maintain uniform fuel bed while following fluctuations in load.

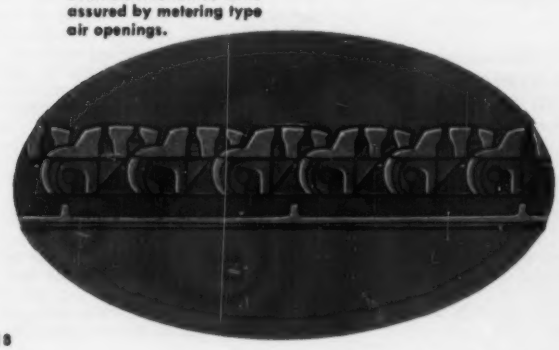
Burns all grades of bituminous and lignite coals, also many kinds of refuse and by-product wastes.

The RotoGrate for boilers to 400,000 pounds steam per hour capacity; other Detroit Stokers for capacities from 3,000 pounds steam per hour.

DETROIT STOKERS COST LESS

Cost equals initial investment plus upkeep plus production losses due to equipment outage. The total is less with Detroit.

Even distribution of air is assured by metering type air openings.



DETROIT SINCE 1898 STOKERS

DETROIT STOKER COMPANY

DIVISION OF UNITED INDUSTRIAL CORPORATION

MAIN OFFICE AND WORKS • MONROE, MICHIGAN

District Offices or Representatives in Principal Cities

8418

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high; and irrational low. False alarms are prevented by means of self-checking every 0.8 sec, manufacturer points out, and logic of the checking channels has been extended to provide automatic localization of failures.

10—Centrifugal pumps for handling of difficult fluids

Model 3199 Pumps, available in two sizes, are designed to meet requirements in chemical process and other industries where relatively small quantities — up to 115 gpm — of corrosives or slurries, thick or abrasive, must be handled for heads up to 150 ft. Products of Goulds Pumps, Inc., they are single stage side suction, open impeller pumps with 1-in. flanged discharge and 1- and 1½-in. flanged suction connections. Standard assembly provides top vertical discharge but horizontal top or bottom discharge position is also available. Impellers have ejector vanes on back wall to prevent entrance of solid material and reduce stuffing box pressure. Stuffing box has five rings of dieformed packing and lantern type liquid seal rings. Tapped in-and-out openings to seal ring allow use of clear liquid seal, clear liquid flush or grease seal to solve individual packing problems when pumping slurries. Pumps come in bronze fitted, all iron, all bronze, 316 stainless steel and Gould-Alloy 20. Full information is in Bulletin 720.5.

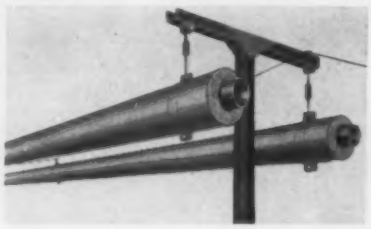
11—Dehydrators prevent contamination of tank contents

Made by The Johnston & Jennings Co., these units serve to prevent dilution and possible contamination of storage tank contents by removing moisture from air taken into tanks as the product is being pumped out. The desiccant material is held in a basket-like drawer with wire mesh top and bottom, which slides

into a gas-tight housing. Air being drawn into the tank, as product is pumped out, passes through the desiccant mass and gives up its moisture. The moisture is absorbed mostly into the pores of the desiccant, consequently the low efficiency of the vacuum relief system is claimed practically unaffected. A layer of "indicator material" on top of the basket-like drawer, and visible through the peep glass, turns from blue, when dry, to pink, and then to white when saturated, showing when the drawer should be replaced with one of dried and reactivated material. Average life of a drawer of desiccant between reactivations ranges from 30 to 100 days. It is available in 2- to 12-in. sizes.

12—Prefab piping systems for overhead and underground lines

For overhead distribution of steam, hot water, process liquids and refrigeration lines, the Plasti-clad System of Ric-wiL, Inc. consists of pipe and insulation covered with aluminum foil, over which are two wrappings of fiber glass cloth integrated within the Plasti-clad material. A final color coat of Plasti-clad is applied to finish the unit. The system is prefabricated complete with expansion loops, anchor units, elbows and T units. Straight run units come in 21-ft lengths.



For underground distribution, a plastic coated system consists of pipe and insulation covered by a spiral welded metal conduit. The conduit is protected against soil and stray current corrosion by a 20- to 25-mil coating of cold-cured epoxy coating reinforced with fiber glass cloth. Company says it is resistant to acids, alkalis and salts; has a high dielectric strength; stands continuous temperatures of 375 F, and does not crack at low temperatures. Thermal coefficient of expansion is said to be nearly the same as steel, so that expansion and contraction of the conduit won't rupture coating.

13—Gage checks water level in storage tanks

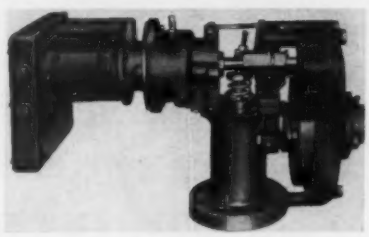
Model 1100 is announced by Universal Valve Co. as an inexpensive water level gage and sampler consisting of a clear plastic tube, insoluble in gasoline, and a simple poppet type valve at the bottom which includes a plastic valve body. Water level sampler is attached to any standard gage pole by two screws, enabling two checks to be made simultaneously. Operated simply by lowering it into underground storage tank until it hits bottom, forcing stem to open valve and allowing sample of liquid to enter tube, it has applications in any liquid, petroleum or chemical storage tank.

14—25-hp fixed center drive with speed ratio up to 8:1

Offered by Gerbing Mfg. Corp., the No. 1325 Type W Roto Cone Fixed Center Drive provides speed change ratio of up to 8 to 1 and 25 hp at 1750 rpm with single variable speed belt. It operates on fixed center shafts. This drive consists of the manually operated Roto Cone used in combination with a spring loaded pulley and a 2¾-in. top width variable speed belt. The manually operated pulley has an integral handwheel. By turning this, the pitch diameters of both pulleys are changed. Speed change is made while the machine is in operation. It is of the rack and pinion gear design to provide equal and opposite movements of both discs. The V-belt travels on a fixed center line, allowing drive to have both pulley hubs on same or alternate sides to each. Used with NEMA motor or other driving source, this drive has 13-in. disc diam, used with a 2¾-in. top width belt, and provides ratios through 5 to 1 at 1750 rpm, and through 7.5 to 1 at 1150 rpm.

15—Brackets for low-cost installation of fixtures

This hanger bracket, No. 1240, for low-cost installation of suspension systems, is offered by Ramset Fastening System, Winchester-Western Div., Olin Mathieson Chemical Corp. It can be secured to concrete or steel by screwing it to Ramset or Shure-Set ¼-in. threaded stud embedded in the work surface. It can be used to hold lighting fixtures, ceiling frameworks and channel, conduit and ducts. Extra large side slots simplify threading of drop wires. Cost is under $6.00 for 100 brackets.



16—Soot blower head for indoor or outdoor use

The D-4-E Rotary Soot Blower Head is designed by Blaw-Knox Co. to use air, saturated or superheated steam, water or slurries — or any combination of these — as the blowing medium without change in equipment. Installation may be on side wall or roof, horizontally or at any angle above horizontal plane. It is built for service through 1500 psi standard. Electric, air or manual drives are available. With electric or air drive, head may be operated by individual push button, or used in automatic-sequential or selective-sequence system controlled from central panel.

17—Valveless gravity filter sets own backwash cycle

The Permutit Co. announces a gravity water filter for municipal and industrial use that features low initial cost versus designed performance, and fully automatic operation. The new design is built around an old device — the siphon. Combined with a filter bed in a compartmented tank, this siphon performs the backwash operation automatically; there are no pumps, valves, gages, or manual or electric controls. Manufacturer states that actuation of the backwash cycle is accomplished at the optimum moment, the filter cannot over- or under-wash, and backwash or rinse water cannot be accidentally run to service. The unit operates on a loss-of-head and can be used wherever gravity feed is feasible.

The unit consists of a vertical cylindrical steel tank divided into three sections: backwash storage chamber (top), filter bed compartment, and collector chamber under a false bottom. The backwash storage space is designed to hold the optimum amount of backwash water in relation to surface area of the filter bed below it. It always fills to the same height and consequently gives a uniform amount of backwash on every cycle. The

filter bed contains standard fine filter sand supported on a collection system of disc-type plastic strainers. Other types of filter material can be used by modifying rate of wash.

18—Repair kit for castings, valves, pumps, molds, machinery

Devcon F Repair Kit, containing a new repair material of unusual strength, toughness and versatility, is announced by Devcon Corp. It consists of two 3-oz self-measuring tubes, one containing the Devcon F and the other, a hardening agent. To use, you simply squeeze equal lengths of each material from the tubes, mix them with a wooden paddle and apply to the part to be repaired. The mixture contains approximately 80 per cent aluminum and 20 per cent improved epoxy resins and modifiers. Company says it does not shrink and exhibits tremendous adhesion to steel, iron, aluminum, bronze, glass and other surfaces. The kit costs under $2.00.

19—Temperature transmitter in gas-actuated model

Added to complement Taylor Instrument Co.'s Sensaire 202T line of mercury-actuated temperature transmitters is a low-cost, gas actuated model for use

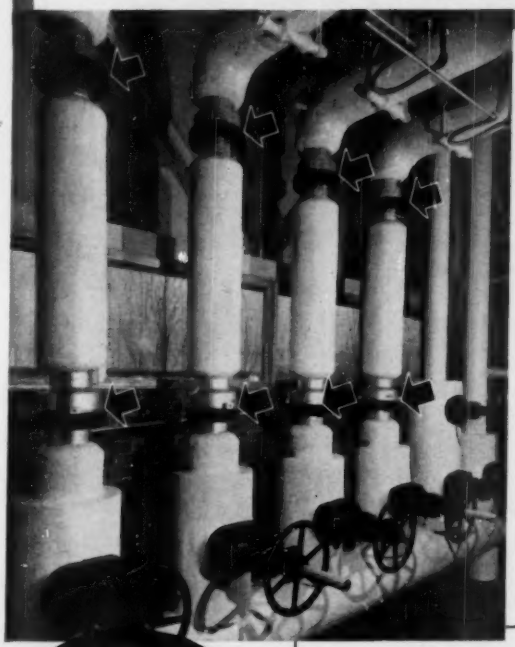
where mercury is prohibited. According to company, measurements as low as −400 F may be made with 1 per cent accuracy. The force-balance instrument is available with standard range spans of 100, 200, and 400 F. Interchangeable, all-welded, thermal systems may be installed in the field when it is desired to change spans. A bi-metallic element attached to force beam compensates for case temperature effects. It is said to minimize immersion errors, especially for long flexible extensions.

20—Liquid chillers are compact and accessible

For air conditioning or industrial cooling applications, the Versare line of hermetic packaged liquid chillers is announced by American Standard, Industrial Div., as featuring versatility, compactness, ease of servicing and safety. Eleven models — in small capacity increments — cover net rated capacities to 67.1 tons, depending on condenser water temperature conditions and desired leaving chilled water temperature. Standard units are also available without condenser and with accessories for remote condenser applications. The package design requires minimum water piping and electrical connections, and the units are slim enough to pass through a 36-in. doorway.

Among safety features incorporated are automatic safety switches for motor

Barco Solves Boiler Piping Expansion Problem



Relieves Strain on Valves

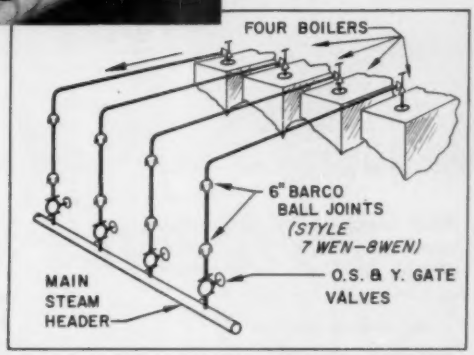
This photograph shows an interesting new installation of eight Barco Flexible Ball Joints (see arrows) on four 250 psi boiler steam lines in a West Coast industrial plant. The schematic diagram (below) shows the piping layout.

Due to the fact that operation of individual boilers is intermittent, complicated expansion, contraction, and torsional movements occur in the piping. All of these movements are easily accommodated with the aid of the Barco Joints, relieving reactive forces on the valves.

BARCO

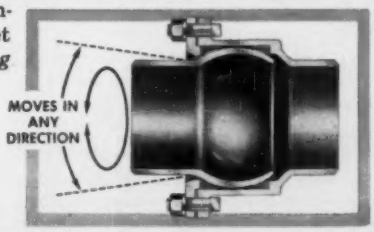
BALL JOINTS

1. Handle Expansion
2. Relieve Torsion



PROBLEM—Originally, in the plant shown above, it was thought that the "spring" in the long runs of piping would take care of *thermal expansion* and *torsional stresses*. SUCH WAS NOT THE CASE. Serious trouble was encountered, tending to crack valve flanges and twisting so they would not seat tight.

ANSWER—Barco Ball Joints solved the problem, LOGICALLY, SIMPLY, ECONOMICALLY. These rugged all-steel joints have no thin wall sections, no critical points of fatigue, no rubber seals. They are practically indestructible. They provide points of flexibility in piping. Easy to engineer. They fit right in the piping; develop no "end thrust"; require no expensive anchoring. Sizes and styles to meet your requirements. *Send for catalog and information.*



BARCO MANUFACTURING CO.
5478 Hough Street, Barrington, Illinois
In Canada: The Holden Co., Ltd., Montreal

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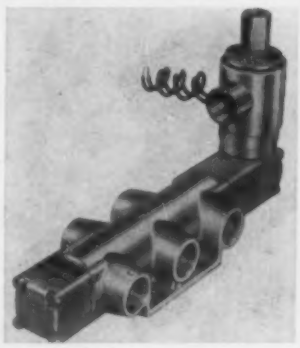
overload, high motor temperature, low oil pressure, high condenser pressure or low cooler pressure. To protect operating and maintenance personnel, the control panel is divided into two separate compartments: one for the 115-v control circuit, and the other for the higher voltage power circuit.

21—Solenoid valves for use in hazardous conditions

Efficient operation of pneumatic and hydraulic fluid control systems under hazardous environmental conditions is claimed possible with these explosion-proof valves of Versa Products Co., Inc. They are enclosed in a forged bronze

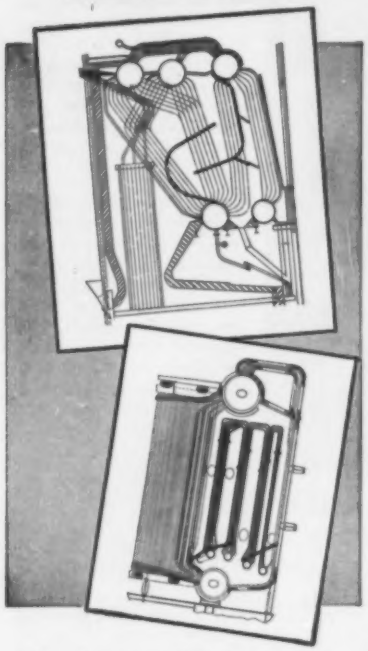


body and available in explosion-proof, dust-proof, waterproof and fungus-proof constructions. Maximum flow-passage capacity in slim-design sizes from ⅛ through ½ in. NPT in two-, three-, four- and five-way types make them suitable for close-quarter installations. They operate on pressures from partial vacuum to 500 psig; 110-v 60-cycle coils are standard. A balanced spool design results in only a small-force requirement to actuate the valve, safeguards it from effects of operating pressures. Solenoid actuator can be rotated to any position; side port or sub-plate models are available for manifold mounting. Further details are in Bulletin 660.

22—Tangential fittings can be joined easily to pipe

Pypon Fittings, designed for nominal temperature, low pressure process piping, can be joined to pipe using equipment normally available in any shop, according to Flowline Corp. Line includes elbows, returns, tees, caps, stub ends and reducers in stainless steel or aluminum, ¼ through 4 in. pipe sizes, Schedule 5S and 10S. Fittings are supplied with long tangents which permits

ONLY ENCO BAFFLES give you all these COST CUTTING FEATURES



These important fuel-saving maintenance-reducing features are obtainable with Enco boiler baffles—*and only with Enco baffles.*

- **Streamlined gas flow**
- **Uniform gas flow**
- **Elimination of bottlenecks**
- **Reduced draft losses**
- **Higher heat transfer**
- **Cleaner heating surfaces**
- **Less use of soot blower**
- **Special provision for expansion**
- **Easy tube replacement**
- **Adaptable to any water-tube boiler, fired by any fuel**

Each application is designed on the basis of more than a quarter century of experience in this specialized branch of power engineering. Installations are made by skilled mechanics.

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75 WEST STREET, NEW YORK 6, N.Y.
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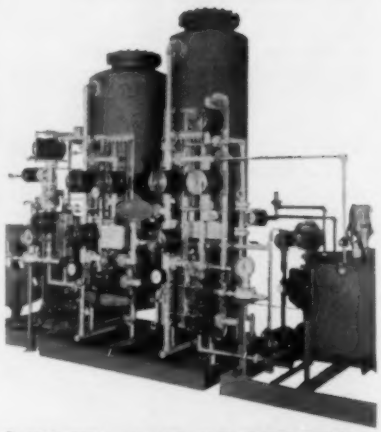
AUTOMATIC DE-I*

ILLCO-WAY DESIGNERS AND BUILDERS
MODERN EQUIPMENT FOR ionXchange



*DE-IONIZER

Here is a typical *fully-automatic* De-Ionizer, skid-mounted, loaded with resins, tested, ready for hook-up in your plant. A complete Control Panel (not shown), built by IWT, is included. Valves are exclusive ILLCO-MATIC, high-density polyethylene, specially designed for ionXchange service, pneumatically-operated, and *proved* reliable in extensive use.

FOR ANY PROCESS REQUIREMENT, OR HIGH-PRESSURE BOILER MAKE-UP

Such De-Ionizers are used to provide extremely pure water, tailored to specifications for all kinds of processes, or to the particular conditions for make-up of modern high-pressure boilers.

TELL US YOUR NEEDS

Our pioneering experience, gained since the very beginning of ion-exchange, is available for the successful solution of your water-treatment problems. Call your IWT representative.

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CANADIAN DIST.: Pumps & Softeners, Ltd., London, Can.

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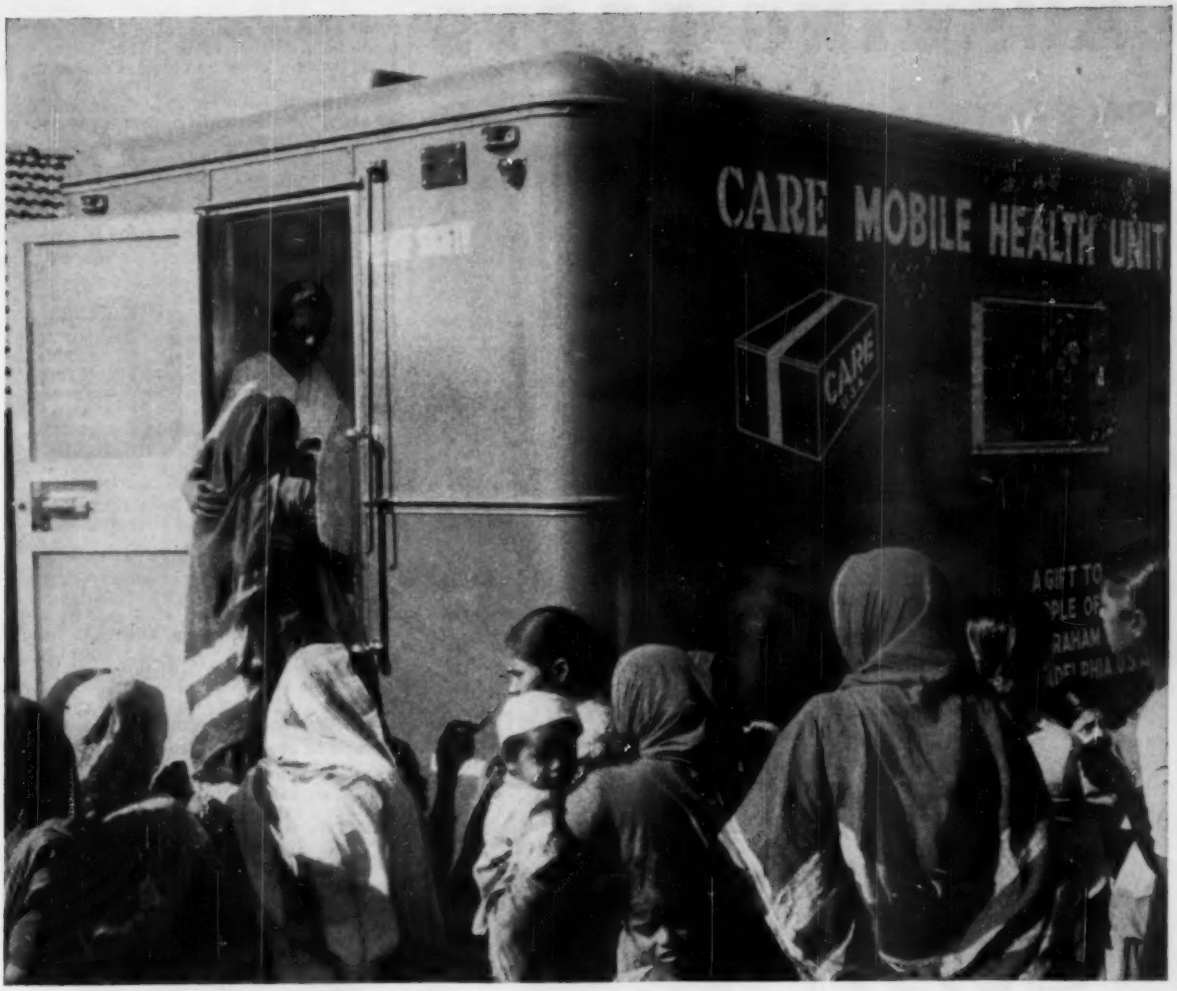

Your CARE dollars save lives

Here is the biggest "CARE package" the people of America ever sent to desperately poor people of other lands: A mobile health unit which brings medical care to four villages in India. It heals the sick. It teaches simple hygiene. It helps people find strength enough to lift themselves by their own bootstraps.

Typical clinic-on-wheels includes examination-operating table, medical and surgical instruments, lab equipment, sterilizers, electric generators; in some areas, film and slide projectors for teaching purposes.

The unit above is sponsored by the Bombay Mothers' and Children's Welfare Society and staffed by a native medical team—doctor, nurse, technician, driver-helper. Diagnosis ... treatment ... surgery ... preventive medicine—all are part of the job.

Currently, 16 such units—provided by you through CARE, but operated and maintained by responsible local groups—are at work in India, Ceylon, Egypt, Poland, Mexico, the Philippines. Urgent appeals for similar units are far beyond available CARE funds.

What does a mobile health unit cost? Around 11,500 dollar bills pooled together. But it treats about 20,000 people a year—that's 58¢ per patient. Divide that by its many years of service ... calculate, if you can, the immeasurable human good every penny does—and you know that CARE dollars ear-marked for health units buy the biggest bargain on earth. Will you help? Send dollars to CARE, New York 16.

CARE COOPERATIVE FOR AMERICAN RELIEF EVERYWHERE, INC. 660 FIRST AVE., NEW YORK 16, N. Y.

Here is $___ towards health unit ☐
food ☐ tools ☐ books ☐
CARE's choice ☐

(PLEASE MAKE CHECKS PAYABLE TO CARE, INC.)

NAME_____

ADDRESS_____

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from *American* PULVERIZER CO.

USER REPORTS

"We've reduced 2,521,000 tons of 2" N & S coal to a ¾" product. Rings and screens have been renewed only once. Replacement parts have cost $0.0016 per ton, including standby parts."

When you figure Costs, the best results come from American Rolling Ring Crushers.

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ORIGINATORS AND MANUFACTURERS OF RING CRUSHERS AND PULVERIZERS

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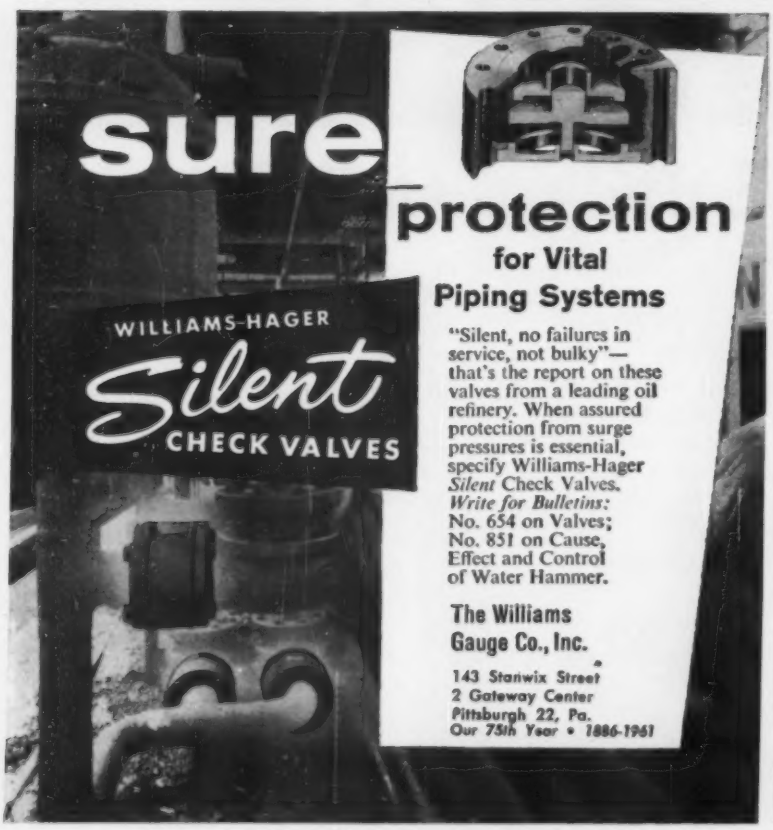
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"Silent, no failures in service, not bulky"— that's the report on these valves from a leading oil refinery. When assured protection from surge pressures is essential, specify Williams-Hager *Silent* Check Valves. *Write for Bulletins:* No. 654 on Valves; No. 851 on Cause, Effect and Control of Water Hammer.
The Williams Gauge Co., Inc.
143 Stanwix Street
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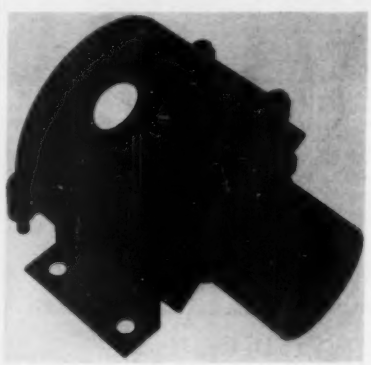
joining them to pipe by rolled-in flanged assemblies, fillet welding, soft soldering, silver brazing, or butt welding. Company says their use, with lightweight or featherweight pipe instead of Schedule 40 pipe, provides greater flow area, reduces weight and effects savings in material cost. Bulletin P59 gives information on these tangential fittings.

23—Long retractable soot blowers are air or electric powered

For travels up to 24 ft and for indoor or outdoor installation, these retractable soot blowers of Copes-Vulcan Div., Blaw-Knox Co., feature dual-motor drive. One motor extends and retracts the lance; the other rotates it. Either traversing or rotating speed may be changed without affecting the other. Vulcan T-30 Mark I-E is electrically driven and Mark 1-A is air powered. Their power packs may be mounted at any of several locations on the soot blower to avoid obstructions or high ambient temperatures. Air, saturated or superheated steam, or water, or any combination of these, may be used as blowing medium. Nozzle pressure can be adjusted externally even while blowing. Working parts are protected by a heavy-gage steel housing. Provision for mounting on boiler wall is built into the blower to reduce cost of installation.

24—Pipe guides control lateral offset and angular rotation

These carbon steel pipe guides support and align piping in which bellows expansion joints and expansion compensators are used. The product, made by Tube Turns Div. of Chemetron Corp., consists of a guide spider to be clamped around the pipe whose movement is be-



ing controlled, and a guide casing, which can be bolted to base or other supporting structures at any angle. There are two standard models: Series A (shown) is for up to 1½-in. insulation, and Series B, up to 2-in. insulation, from ¾- to 30-in. pipe size. Both provide for 6 in. of axial movement and are adapted to greater traverse by increasing the length of the spider to equal the pipe movement. Guide casings are 3 in. long for pipe sizes of 2½ in. and smaller, and 6 in. long for those 3 in. and larger.

25—Valve offers working pressure of 10,000 psi

Offered by Republic Mfg. Co. in a variety of models — two-way, three-way and four-way with closed and open centers, this valve is reported to have a

working pressure of 10,000 psi, to withstand 15,000 psi surge, and to have a burst pressure of over 30,000 psi. Of heavy, one-piece stainless steel body construction, with non-corrosive internal parts, it is available for air, water,

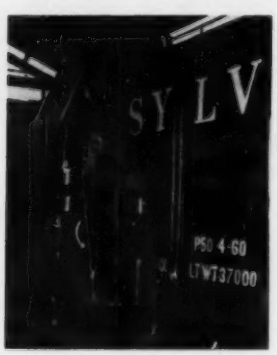
and oil services. Lo-torq sliding seals and selector disks are stainless steel. Seals are wear-compensating, sealing tighter as they wear in. Made in sizes ¼ to 1 in., with choice of internal pipe, or internal straight (gasket seal) threads.

26—Testing unit is low-cost three-purpose tool

The handy little Chek-Lite of BullDog Electric Products Div. is a voltage tester, continuity tester and flashlight. It's about as big as a package of king-size cigarettes and sells for around $5.00.

27—Car shaker strikes top as well as side of car

Model LE-10 Car Shaker hangs on side of open top, hopper bottom railroad cars and does not require any clamping de-



vices, according to Eastern Constructors, Inc. The shaker pounds on top edge of car side with heavy impacts which shake entire car. In addition, it strikes lower area of car side to dislodge tightly packed materials in car pockets. Shaker is available in 10- or 15-hp sizes.

28—Desuperheater performs at 50:1 turn-down ratios

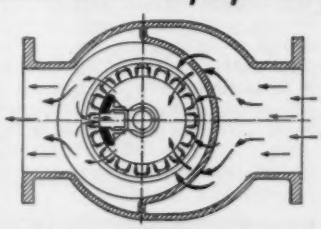
Introduced by Schutte and Koerting Co., the Fig. 6970 is a steam ejector, atomizing type desuperheater reported to perform dependably with turn-down ratios as high as 50:1 in ranges of 10 to 50 F above saturation temperature, when equipped with adequate pressure and temperature controls. The only

Elliott type K self-cleaning water strainer

More than 100 Elliott strainers serve one New Jersey refinery

24 are special self-cleaning strainers, 2 of which are seen upper left. The others are standard Elliott Twin and Single Strainers, protecting millions of dollars of equipment.

Elliott type K self-cleaning strainers are designed for cleaning water containing relatively large quantities of foreign matter. Diagram on right shows how they clean themselves, automatically. A revolving sealing box seals off and cleans one unit after another continuously by a reversal of flow of clean water from the discharge side of the strainer. Maintenance is small, saving many man-hours. Available in 4-in. to 36-in. sizes.



Cross-section of self-cleaning strainer.

AO-1

Contact your nearby Elliott District Office or write Elliott Company, Strainer Department, Jeannette, Pa., for complete descriptive details.

ELLIOTT Company

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PATENTED
FULL 4½" DIAL FACE. Stem can be placed at any angle and case can be rotated to any readable position.
1 RIGID STEM DIAL THERMOMETER tapered bulb, interchangeable with standard industrial thermometer separable socket. (As illustrated above.)
2 WALL MOUNTED DIAL THERMOMETER with flexible connecting armor. Case adjustable to easy reading position.
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ALL THREE TYPES HAVE A FULL 4½" DIAL FACE.

■ **for accuracy:** Mercury actuated . . . Compensated by Invar. Guaranteed Accurate 1 scale division. ■ **for angularity:** Can be adjusted to most readable position at any angle desired. ■ **for readability:** Bold Black Numbers . . . 11" of scale Reading Dial face can always be placed in easiest readable position. ■ **for interchangeability:** Also specify "PALMER" Separable sockets as they are interchangeable for Dial or Industrial type Thermometers.

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PALMER THERMOMETERS, INC.
Norwood Ave., Cincinnati 12, Ohio
MFRS. OF INDUSTRIAL LABORATORY, RECORDING AND DIAL THERMOMETERS

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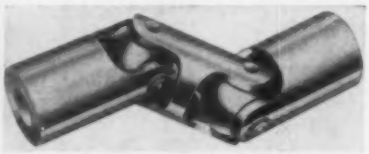
other limitation regards atomizing steam pressure which must be at least 1½ times desuperheater steam pressure and 2 per cent of total flow. The unit also features straight-through-flow design and is made for installation directly in the superheated steam line.

The Fig. 6970 was developed to overcome the problem of erroneous reading by the temperature sensing device caused by "falling out" of even finely atomized water from the stream of steam, without being vaporized, at low pipe velocities. Such erroneous reading causes the temperature controller to respond by causing excess water to be pumped into the desuper-heater. The Fig. 6970 corrects this by collecting unvaporized cooling water from the steam pipe line and recirculating it to the atomizer. At normal flow rates, when there is no excess water collected in the line, the unit operates in the conventional steam-atomizing manner.

29—Universal joints handle speeds up to 1500 rpm

Lovejoy Flexible Coupling Co. has introduced a line of universal joints for industrial applications up to 1500 rpm, in both single and double (shown) types

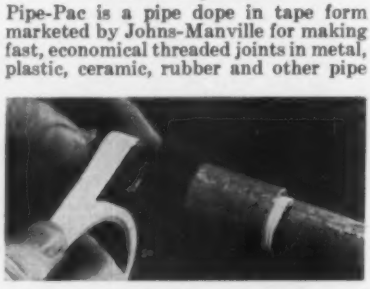


and a wide range of sizes. Single joints are designed for operation through full working angle of 40 deg and double joints through 80 deg. Rated at 0.35 to 190 hp at 100 rpm, they come in sizes from ⅜ to 4 in. and are available with square bore. Catalog 61-D gives data.

Reader Service Cards on pages 85–86 make it easy to get further information on any of these products. Just circle the item numbers of the products you want to know more about.

30—Pipe dope comes in convenient tape form

Pipe-Pac is a pipe dope in tape form marketed by Johns-Manville for making fast, economical threaded joints in metal, plastic, ceramic, rubber and other pipe



materials. It reportedly withstands temperatures from −300 to 500 F and can be used for carrying air, oil, water, gas, steam, solvents and chemicals, and corrosive materials. Company says tape will not cake or harden, and will prevent freezing of joint and allow easy disassembly.

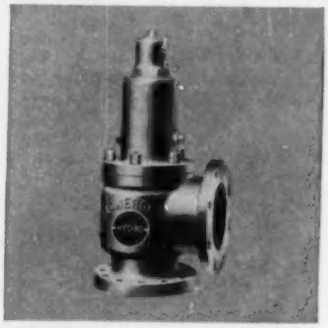
THE LONERGAN LINE

HOW TO SAVE WEAR AND TEAR ON MEN AND VALVES

by A. J. Schmidt, Chief Engineer

Power plant users of relief valves in liquid service are undoubtedly all too familiar with chattering. Valves hammer away, annoying plant personnel and running up maintenance bills.

Even with this undesirable operation, these



valves have been acceptable for application where the valves are seldom, if ever, called upon to relieve. For use under critical applications, such as pump-by-pass, where the valve is normally open, or where opening is a common occurrence, it has been necessary to use expensive diaphragm or piston operated valves to eliminate objectionable chattering.

A new series of valves, called Lonergan Hydro-Valves have been under test in dozens of leading plants for the past three years. As a result, Lonergan can provide power plant operators with a valve that is guaranteed not to hammer, chatter or drum on any application, by-pass or emergency relief. At the same time, full-rated liquid flow is maintained. The chatter free operation is provided by a patented, unique design of throat, seat and baffle construction. Use of the Hydro-Valve helps to: save human nerves; prevent loss of plant fuel or product; reduce maintenance on valves and piping; and eliminate interference with delicate control systems. Hydro-Valves are available in all regular body and trim materials in sizes ranging from 1 to 8 inches.

Full details and descriptions are available in our new Hydro-Valve bulletin. Why not write for your copy today?

Alvin J. Schmidt

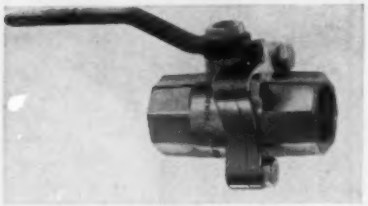
Lonergan

J. E. LONERGAN CO., 207 RACE STREET
PHILADELPHIA 6, PA. SINCE 1872

For more data circle 540 on Post Card

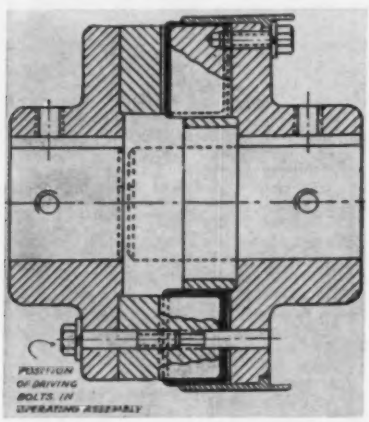
31—Ball valves resist abrasive wear and leakage

The BL-300 Forged Naval Bronze Valve, introduced by R-P & C Valve Div., American Chain & Cable Co., Inc., is rated at 300 lb for water, oil or gas service at a maximum of 250 F. It comes in sizes ½ to 2 in. inclusive. Company says it requires only a quick quarter turn of handle to open or close. Auto-mating seats are designed for positive sealing in either flow direction. Wiping action of ball across seats forces out foreign matter, company says, preventing abrasion.



32—Flexible couplings allow rotation or radial removal

Standard-duty (Type CQ) and heavy-duty (Type HQ) flexible couplings incorporate one set of jaws in removable ring form, permitting both independent rotation or radial removal of connected machinery. This feature is advantageous on gasoline, steam or diesel engine applications where driven machinery must be disconnected in order to set or time the engine. Pulling a removable jaw ring outward provides enough clearance for independent rotation of either end of coupling. By reversing a set of cap screws from one body to the other, connected machinery can be removed radially without disturbing power transmitting elements. Products of Lovejoy Flexible Coupling Co., Type CQ Couplings have maximum bores from 1⅜ to 5½ in., from 2.58 hp to 156 hp at 100 rpm; and Type HQ, 1¾ to 8½ in., from 7.77 to 810 hp at 100 rpm.

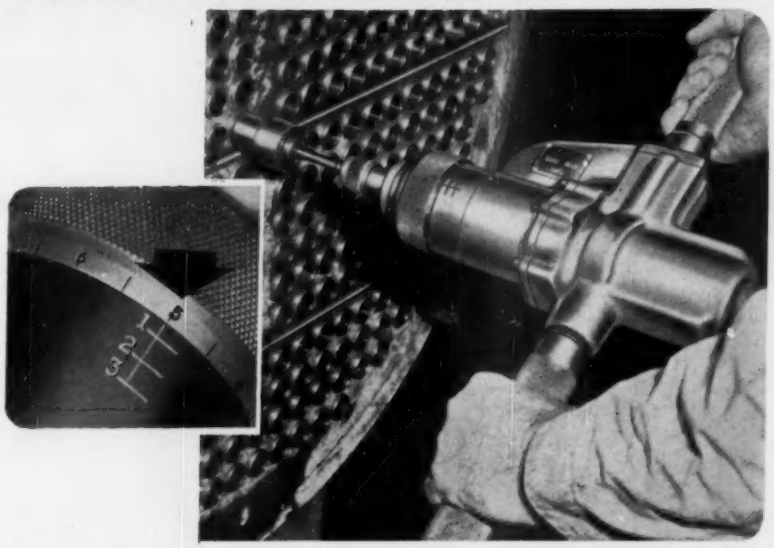


33—Pushbutton and indicating light in one unit

An oil tight, illuminated pushbutton combining functions of a pushbutton and an indicating light in a single unit is introduced by Cutler-Hammer, Inc. It incorporates a color-coded molded type transformer designed to be immune to

roll 12 tubes every minute with AIRETROL

Airetrol combines rugged air power and precision expansion control to make industrial tube fabrication fast . . . easy . . . economical. One man, operating lightweight Airetrol, can roll 12 tubes a minute . . . to .001″ accuracy.



The operator dials the desired setting on Airetrol's micrometer scale; the precision torque-sensing mechanism automatically stops expansion at this predetermined setting. Results: faster tube fabrication; uniformly tight joints and fewer in-service tube failures.

And, for efficient tube maintenance, you can depend on Airetool's full line of pneumatic tools. For instance, with the powerful Airetool CC-475 Condenser Cleaner, one man can remove the toughest deposits from completely plugged tubes; a built-in flushing system cools the drill head and washes away scale and debris.

Get the complete story on time and money-saving Airetool tube fabrication and maintenance equipment today. Write for Bulletin 64.

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STICKLE OPEN COIL FEEDWATER HEATER

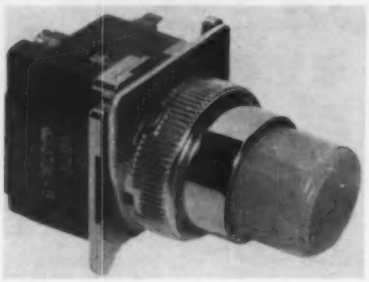
Only Stickle open coil tray-type feedwater heaters are backed by this important guarantee. And the guarantee has been unchallanged since 1912 when Stickle built the first unit of this type. Some early models are still in continuous operation after 46 years! Now custom built in deaerating and non-deaerating types, in a wide variety of styles, to meet each space and storage requirement. Capacity range from 3,000 to 300,000 pounds per hour. It pays to specify Stickle.

FREE BULLETIN!
For helpful data on feedwater heaters, and a look at the various Stickle models, write for 12-page Bulletin 117-A.

STICKLE STEAM SPECIALTIES CO.
2241 Valley Ave. • Indianapolis 18, Ind.

For more data circle 542 on Post Card

voltage surge lamp damage, and it can operate with multiple contact blocks with any combination of normally-open or normally-closed contacts. Other features include base and one-hole mounting, plastic lenses in red, blue, amber, green, clear or white, and a positive mechanical "feel." It is available for 110- to 550-v applications. Publication LO-104 gives information.



34—Welded bonnet valves have hard faced seats

Henry Vogt Machine Co.'s forged steel welded bonnet GP Valves are available in gate and globe types with screw ends or socket weld ends as desired. General purpose valves, they have hard faced seating surface for longer, drop-tight service and are designed to give maximum resistance to erosion, corrosion and galling. Valve is available from ¼ to 2 in. sizes for 150–800 lb service.

Described on these pages are new and improved products. Use Reader Service Cards on pages 85–86 to ask for more information on them. Just circle the item numbers of all the products in which you are interested.

35—Relief valve designed for handling corrosives

No. 1911, a relief valve with a polyvinyl chloride body is announced by Atlas Valve Co. for corrosive fluid handling applications in chemical and other industries. It is reported highly resistant to corrosion by acids, alkalis, salt solution, alcohol etc. This valve, available in sizes to 2 in., can be used at tempera-

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MODEL BR
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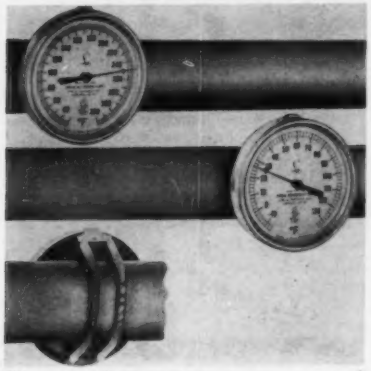
tures to 160 F and pressures to 120 psi. Reduced pressure ranges are 5-15, 10-80 and 50-120 psi. The spring-loaded, diaphragm-actuated, single seat relief

valve is designed to modulate in response to upstream pressure. At set pressure the valve remains closed and opens when upstream pressure increases over the set pressure.

36—Clip-on thermometer reads pipe surface temperatures

These pipe fitting thermometers clip to steam, water refrigeration, gas and other pipes by means of twin spiral spring clips. Products of The Abrax Instrument Corp., the instruments can be attached or removed from pipes without



alteration of pipes. The precalibrated thermometers have 2½-in. diam dials, silvered, with black figures, are graduated 2-deg divisions, and can be used for pipes to 3½ in. diam. Model APFT 460 comes in range from 32 to 320 F and Model APFT 461 for the colder ranges of −14 to 134 F. Price of either model of these easily attached and removed pipe fitting thermometers is around $13.00. Literature available.

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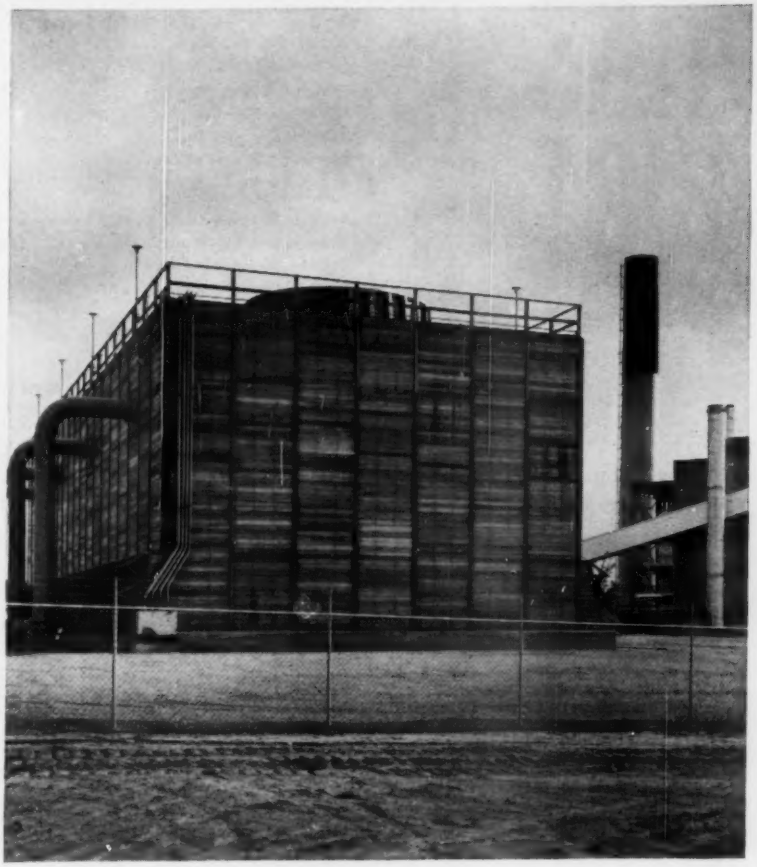
is receiving applications for Senior Operators, Control Operators, and Plant Electricians for employment in a new 66,000 KW Steam-Electric Generating Plant 50 miles south of San Antonio, Texas. Send complete resume to Medina Electric Cooperative, Inc., Box 1028, Pearsall, Texas.

CORROSION COSTS CAN BE LOWERED



No matter how you figure it—in terms of replacement costs, treatment costs or higher production—Hagan can save you money by keeping cooling and service water systems at top efficiency. Complete treatment recommendations, based on experience with water problems in every kind of industry, are backed up by continuing service after treatment is started. Hagan's methods have achieved these results:

LOWER CHEMICAL COSTS: In most systems, treatment is more effective. This means that smaller amounts of chemicals can be used.

LOWER WATER COSTS: With more effective treatment, it is frequently possible to maintain higher solid concentrations in cooling water. This means less makeup water, and consequent savings in overall water costs.

BETTER RESULTS: In many plants, Hagan methods have reduced corrosion rates to 1 mil per year or less. At the same time, troublesome deposits were eliminated, increasing equipment efficiency, and overall chemical costs were lowered.

A letter or phone call will put Hagan Engineers to work on your particular water problem.

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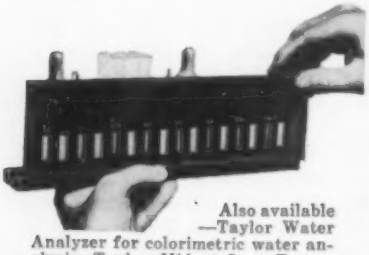

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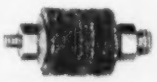
Expanding scraper and replaceable element.

Expanding brush and replaceable element.



Sectional wire brush.

Air valve for one-man operation.

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An air valve directly behind the Rotojet motor permits one-man operation. Very little headroom is required, and either vertical or horizontal tubes can be cleaned.

Simplicity of Rotojet design and precision construction assure long service, efficient use of power, and freedom from trouble. Economical brushes, cutters, and scrapers meet practically any requirement.

Send for Bulletin J-410.

ROTOJET® Junior TUBE CLEANERS

ELLIOTT COMPANY – ROTO PLANT

Tube Cleaner Specialists Since 1910

147 Sussex Avenue, Newark, N. J.

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Fullerton, California

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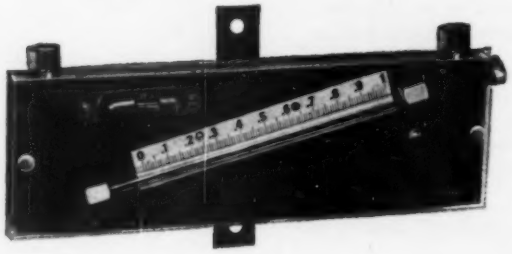
YOU GET *accuracy with economy in this new Ellison "AFS" Air Filter Gage*



The new Ellison Series AFS Air Filter Gages show when air filters have become clogged and need changing. Easy to install. Easy to read. Clear plastic snap-on cover keeps scale clean. A really accurate, well-made instrument at a surprisingly low cost. Eliminate guesswork and cut costs—no need to change filters until gage so indicates. The "AFS" is a new addition to the most complete line of air filter gages —the Ellison Line. A gage to fit every budget! Send for Bulletin 214-C.

SINCE 1896

ELLISON DRAFT GAGE CO., INC.
550 W. MONROE STREET, CHICAGO 6, ILLINOIS

Draft Gages, Bell and Diafram—Inclined Draft Gages—Portable Inclined Tube Gages—Vertical Tube Gages, Oil, Heavy Liquid, Mercury, Single and Multi-tube—U-gages Stationary and Portable—Air Filter Gages, Complete Line—Pitot Tubes—U-Path Steam Calorimeters—Portable Gas Analyzers, Orsat Type—Alarm Systems—Orifice Flanges and Plates—Flow Tube Meters—Condensate Traps.

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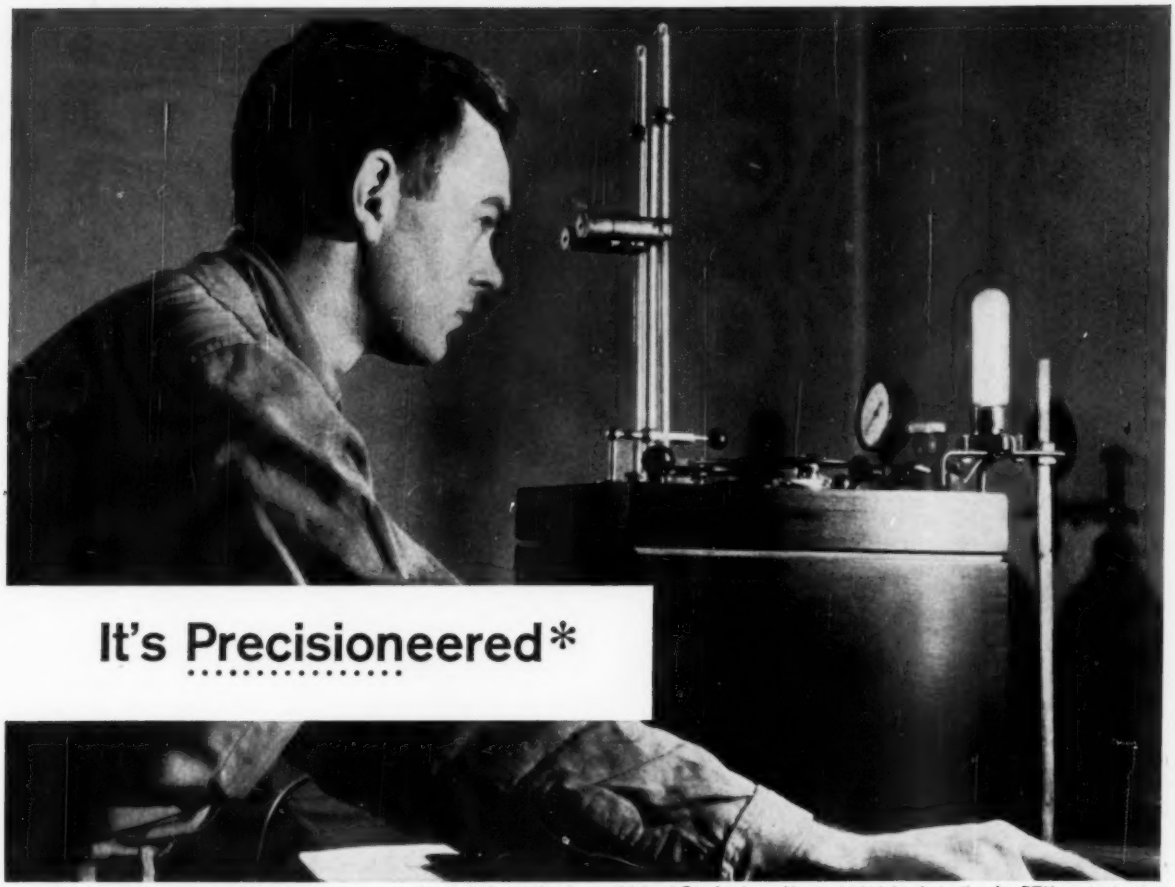
The easiest—and quickest—way to order bulletins and catalogs described in this magazine is to use the postage-free Reader Service Cards on pages 85–86.

All you need to do is circle the item numbers of those you want. Then fill in your name, job title, company name and address—and mail the card.

You may also use the Reader Service Cards to request information on products described, or literature mentioned in the ads—just circle the number below the ad.

How is it possible for Island Creek coal to lower the cost per 1000 pounds of steam? . . .



It's Precisioneered*

Regular and frequent quality control tests are made on coal samples from all Island Creek mines. Here a technician is testing for BTU content.

* PRECISIONEERING is a chain of controlled events that actually begins and ends at your burning equipment. It starts with the question: What kind of coal does your equipment require to produce steam at the lowest net cost per 1000 lbs.? It provides the answer, through penetrating engineering and evaluation studies. It produces the answer . . . with superior seams of coal prepared exactly to your determined specifications in modern preparation plants, using precision engineering techniques and strictest laboratory controls. We'd welcome a chance to discuss the possible reduction of your net costs through Precisioneering. Write. Or phone. No obligation, of course.

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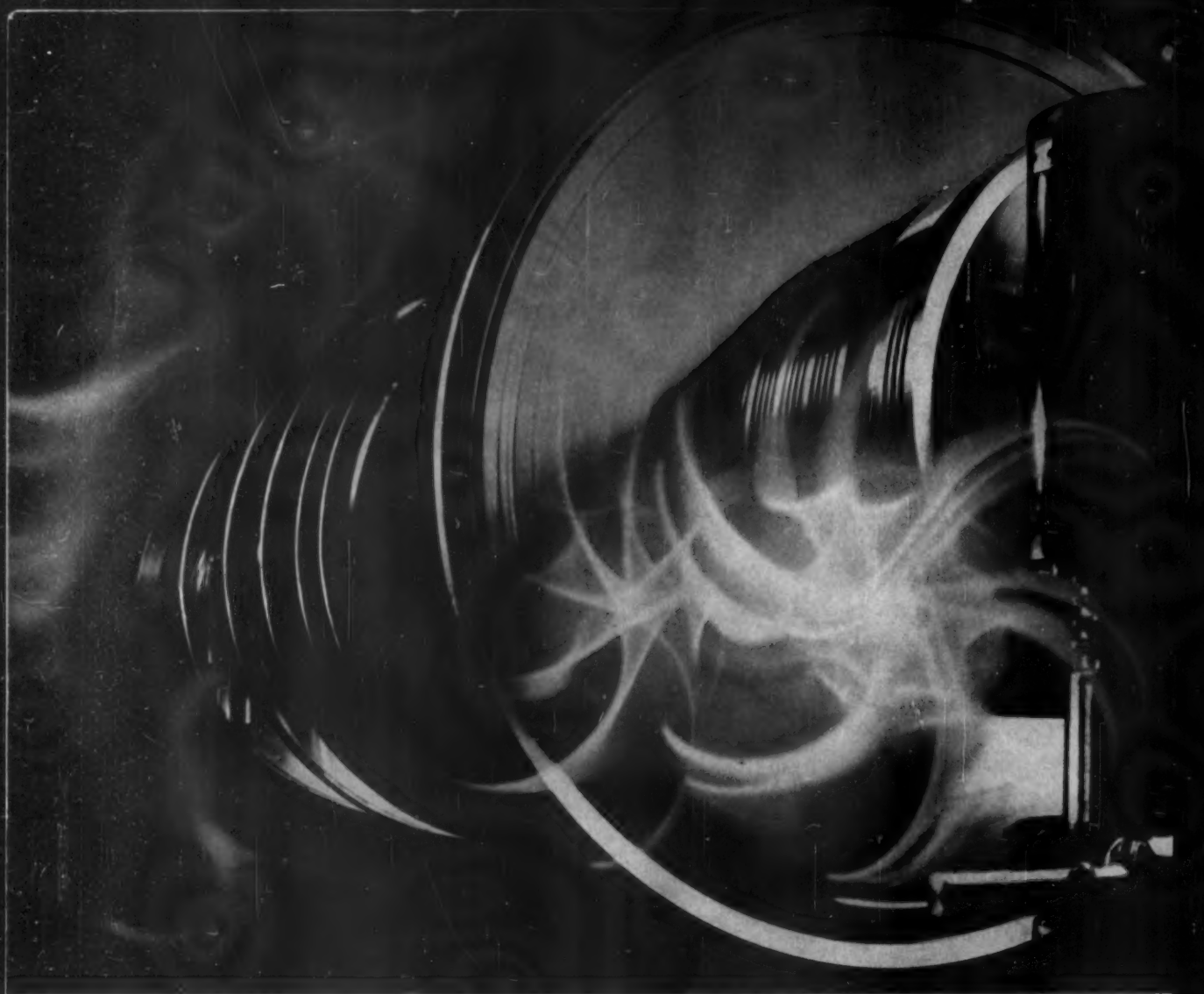

Turbine rotor on dynamic balancing machine—special photographic impression

HOW TO BALANCE "n" TURBINE VARIABLES

This rotor was designed in light of the "n" variables that affect turbine design. No one really knows the number—each installation is different. But they begin with steam pressure and temperature, exhaust steam pressure(s), horsepower and speed requirements, controls, efficiency requirements, and, of course, the nature of the individual application.

Balanced properly, these variables will produce extreme reliability—what we at Worthington believe to be the single most important factor in turbine design.

Balancing these factors in design is, of course, the work of power engineers and turbine specialists. But, it is desirable to have *every* person who is engaged in selection, operation and maintenance familiar with the many factors in mechanical drive turbine design. To help those of your people concerned with turbine application we have just prepared "Let's Talk Turbines." It's a primer on API specifications and other subjects such as turbine types, construction, governing systems and lubrication methods. Write Worthington Corporation, Section 48-12, Wellsville, N. Y.

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